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The White-tailed Deer of Cades Cove: Population Status, Movements and Survey of Infectious Diseases

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THE WHITE-TAILED DEER OF CADES COVE: POPULATION STATUS, MOVEMENTS AND SURVEY OF INFECTIOUS DISEASES

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SUMMARY

A study was conducted on the population dynamics, movement ecology, and diseases of white-tailed deer in Cades Cove, Great Smoky Mountains National Park, from 1980 to 1985. Data on population dynamics and movement patterns were collected in 1983-85, while serologic surveillance for infectious diseases was conducted from 1980 to 1985.

The deer population was estimated using 2 techniques: nighttime roadside spotlight counts, and mark-recapture estimates. Both estimators provided reasonable, though different, results. Spotlight counts yielded an estimate of 0.38 deer/ha (2.63 ha/deer) and monthly mark-recapture estimates (not including fawns) averaged 0.23 deer/ha (4.4 ha/deer). Significant seasonal variation ($P<0.001$) existed in the spotlight count estimates, but mark-recapture estimates were not as variable ($P=0.606$). The seasonal variation observed in spotlight counts was probably due to changes in habitat utilization patterns.

Habitat utilization changes did not affect mark-recapture estimates. Assuming that adequate sample sizes can be obtained, these appear to be the more reliable of the two estimators. Spotlight count estimates are most reliable during spring when utilization of fields by deer is highest, allowing for a higher proportion of the population to be censused.

The adult sex ratio estimated from dawn/dusk counts conducted in August and November of 1983 and 1984 was 72 bucks to 100 does. There was no significant difference in observed sex ratios between 1983 and 1984 ($P>0.5$). Compared to adult sex ratios observed in 1978-79 (33 bucks to 100 does), the sex ratio observed in the present study apparently reflected the cumulative effects of removing primarily does during deer translocations conducted from 1981-84.

Reproductive information on the deer herd of Cades Cove was obtained from fawn:doe ratio counts, reproductive tracts collected from carcasses of does, and from reproductive data collected during summer. Fawn-at-heel counts (fawns:does) ranged from 18:100 in 1984 to 20:100 in 1985, suggesting a low rate of productivity for this deer herd.

There was no evidence during the study that fawns bred and reproduced, and the percentage of adult (2+ years old) females lactating was 32% and 72% in 1983 and 1984, respectively. The difference in reproductive rates observed in 1983 and 1984 was not detected by fawn-at-heel counts. It is suspected that because of behavioral patterns of fawns, fawn-at-heel counts are probably not reliable indicators of productivity. The reproductive rates observed in the Cades Cove deer herd are low compared to most other deer herds and are likely the result of a dense population competing for finite food resources.

Limited data on age ratios of females in capture samples indicated that female fawn mortality rates were approximately 25%. Data on mortalities suggested that predation was one of the major (27%) causes of death, with dogs or coyotes suspected as the major predators. Most (60%) of the deer carcasses found were bucks, suggesting that males were more susceptible to mortality factors than females.

Twenty-one deer, 10 males and 11 females, were fitted with radio transmitter packages, and monitored for an average of 258 days (range 23 to 480 days). The mean annual home range size was 147 ha. Analysis of variance demonstrated that annual home ranges were significantly influenced by sex ($P=0.0076$) and the presence of cattle within a home range ($P=0.0252$); males had larger home ranges than females, and deer that associated frequently with cattle had larger annual ranges than other deer. Deer that associated with cattle also moved at greater hourly rates than other deer.

Seasonally, home ranges were the largest during spring (74 ha) and winter (57 ha). Average home range size during rut (November 16-December 15) was smaller than other seasons, but most bucks exhibited significant shifts in their activity centers during this time. Overall, most shifts in activity centers were observed from winter to spring (64%) and from spring to summer (42%), probably reflecting behavioral responses to changing food supplies.

Dispersals from the Cove by radiocollared deer were not documented in the present study. Data on the locations of recaptured deer demonstrated that the mean distance between captures was 622 m (range 0 - 3400 m). Two of 9 (22%) young males had recapture distances greater than 2000 m, suggesting possible dispersal tendencies in these deer.

Analysis of telemetry data for trends in habitat utilization patterns indicated that radiocollared deer used hay fields more than expected and wooded areas less than expected based on their available proportions. This trend was observed in every season except winter when both habitat categories were used in proportion to their availability. Apparently, hay fields were important to deer as feeding areas during most times of the year. Telemetry data also demonstrated that deer changed their movement patterns in response to the moving of livestock into temporary pastures. Once livestock were moved out of a temporary pasture, deer resumed utilization of these areas.

From 1980 to 1985, 590 blood samples were collected from 518 deer, with some deer recaptured one or two times. The percent of the estimated herd sampled ranged from 8% (1980) to 28% (1984)

Succinylcholine chloride administered by darts was used almost exclusively to immobilize deer. Darting-related mortalities ranged from 7.5% to 28% and was related to the experience of the darter and availability of resuscitative equipment. Young males (< 1.5 years) were at increased risk of mortality due to factors that are not fully understood.

Blood samples were also collected from 56 cattle pastured in the Cove. This represented approximately 13% of the herd.

Blood samples from deer and cattle were stored at the UT College of Veterinary Medicine. Samples were tested for the presence of antibody to hemorrhagic disease viruses (bluetongue and epizootic hemorrhagic disease), leptospirosis, bovine virus diarrhea virus, infectious bovine rhinotracheitis virus, anaplasmosis, and brucellosis. Antibody was found for all agents except brucellosis.

Hemorrhagic disease can be devastating to white-tailed deer and was probably responsible for a major die off in the Cove in the early 70's. Five deer were seropositive during the current study period for at least one of the hemorrhagic disease viruses. Most titers were very low and virus was not isolated from any of these deer.

In addition to the 5 seropositive deer, necropsies were performed on two deer with symptomatology and lesions suggestive of hemorrhagic disease. Bluetongue virus was isolated from one of these deer. None of the cattle samples were serologically positive and no evidence of clinical disease suggestive of hemorrhagic disease viruses was noted in cattle.

In order for an epizootic of hemorrhagic disease to occur, the agent must be present, the deer herd should be relatively dense, and there should be an abundance of the appropriate vector. The first two criteria are present in the Cove, but collateral research indicated a lack of optimal vector habitat and a subsequent scarcity of the appropriate vector.

Leptospirosis is caused by a bacteria that can infect a wide range of wild and domestic mammals. Deer and cattle sera were tested for the presence of antibody for the following serovars: pomona, hardjo, grippotyphosa, icterohemorrhagiae, and canicola. One hundred and eighteen deer (22.8%) were seropositive for one or more of four leptospire serovars. No samples were positive for grippotyphosa serovar.

The presence and distribution of positive pomona serovar titers was similar to other reports. Very few deer were found to be positive for the icterohemorrhagiae and canicola serovars.

The most interesting finding was the high prevalence of antibody titer to the hardjo serovar. This serovar is associated with cattle. The leptospirosis profile of the cattle supported the theory that the hardjo serovar was being spread to deer from the cattle.

Age class and sex of deer were strong risk factors for leptospirosis seropositivity. Adult ($\geq$ 1.5 years) male deer were much more likely to be seropositive than the other age class and sex groups (P=0.001). Adult bucks may play a significant role in the dispersion of leptospirosis because of their larger home range and the use of urine to mark their territory.

Bovine virus diarrhea (BVD) is a virus disease of cattle. The potential impact of this virus on deer is poorly understood. Twenty-seven (5.2%) Cove deer and 3 (5.4%) of the cattle were positive for BVD. Two suspected clinical cases of BVD occurred in Cove deer during the study period.

Infectious bovine rhinotracheitis (IBR) is another virus disease of cattle. Only serologic evidence of infection in deer has been reported. Twenty (3.9%) Cove deer and 6 (10.7%) cows were seropositive for IBR. Clinical disease in deer due to IBR infection has not been reported and was not observed in this study. However, disease associated with IBR infection was noted in cattle during this study.

Serologic evidence of anaplasmosis infection was found in 4 Cove deer. However, confirmation of the presence of this agent by animal innoculation was not conducted. No deer were positive for brucellosis and the cattle herd is considered by regulatory officials to be free of the disease.

INTRODUCTION

Great Smoky Mountains National Park (GSMNP) is the most visited Park in the national park system. Over 8 million people visit the Park each year (USDI 1982). Within the Park, Cades Cove is one of the most visited areas. Over 250,000 vehicles used the Cades Cove Loop Road during 1983 (National Park Service records). The Cove offers visitors passive enjoyment via a scenic drive or the opportunity to actively explore the area on hiking trails or on horseback.

One of the major reasons people give for visiting the Cove is the opportunity to view wildlife. The white-tailed deer (Odocoileus virginianus) herd represents one of the most prized species available for viewing by visitors (Hastings 1986). Because of the intrinsic value of this wildlife resource, any situations or events that might jeopardize the health or status of this herd is of major concern.

Because most major predators of white-tailed deer have been extirpated from the Park and because hunting is not allowed, two major pressures that control deer populations are missing. The density of the herd is one of the highest recorded in the Southeast (Kiningham 1980). Dense deer populations place great pressure on food resources. In addition, dense populations are more likely to experience epizootics of disease, a situation which was graphically illustrated in 1971 when a major die-off occurred in the Cove deer herd due to hemorrhagic disease (Fox and Pelton 1973).

White-tailed deer were extremely scarce in GSMNP during the late 1930's and managers considered a restocking program at that time (Stupka 1938). However, stocking was never initiated, and the deer population has since grown to park-wide abundance, with some areas, such as Cades Cove, containing dense populations.

The Cades Cove deer population has been monitored periodically by researchers since 1970. As mentioned, a major die off due to hemorrhagic disease was documented in 1971, resulting in an observed 84% decrease of field utilization by deer (Fox and Pelton 1973). However, the population returned to pre-die off levels within a year. The density of the population continued to increase in the 1970's to about 0.43 deer/ha in 1978-79 (Burst and Pelton 1978, Kiningham 1980). Several other studies have been conducted on the Cove deer, focusing on their impacts on vegetation (Bratton 1979a), population genetics (Major et al. 1984), and assessment of conditional status through blood chemistry (Dlutkowski 1985). Because of concern over the high density of the herd, the Resources Management Division in cooperation with Tennessee Wildlife Resource Agency (TWRA) initiated a series of deer removals from the Cove in 1981. The removed deer were transplanted to other areas of east Tennessee as part of Tennessee's deer restoration program.

In addition to the deer removals, a study was initiated in 1980 to assess the status and potential impacts of infectious diseases on the Cades Cove deer herd. In 1983, studies on movement ecology and population status were added to the project in order to provide supportive data and understanding of the dynamics of some of the diseases being monitored in the Cove deer population.

This project continued to 1985 and emphasized the potential impact of the following diseases: hemorrhagic disease, leptospirosis, bovine virus diarrhea, infectious bovine rhinotracheitis, anaplasmosis and brucellosis. The following is a report on the findings of this study with an assessment of the potential impact of each of these diseases as well as recommendations for future control or management.

STUDY AREA

Cades Cove is a pastoral and wooded valley surrounded by mountains. It is situated in the northwest section of Great Smoky Mountains National Park (Figure 1), and is in the National Register of Historic Places. The Cove consists of 1863 ha (4600 acres).

As a historic area, the Cove is managed primarily for its cultural resources (USDI 1982). Management strategies consist of maintaining restored historic structures, mowing

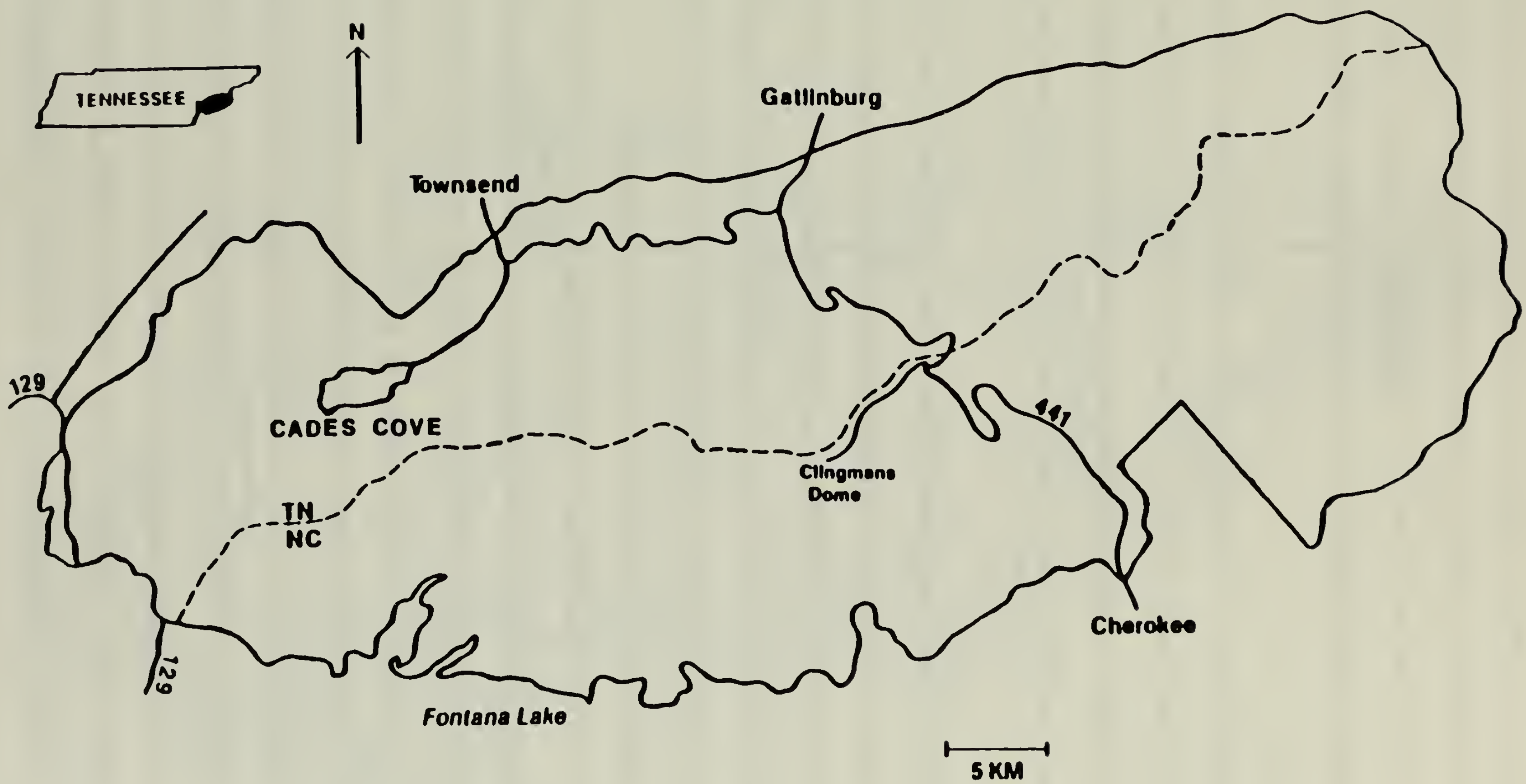

Figure 1. Map of the Great Smoky Mountains National Park (reprinted from Hastings 1986).

fields for hay, and grazing of livestock. The current system of leasing for hay operations and cattle grazing was developed in 1967. The system originally allowed for grazing about 1500 animal units (1 unit=1 cow, or a cow and a calf), but was reduced to about 500 in 1977. About 40 concession owned horses and 6-8 National Park Service (NPS) horses are also pastured in the Cove.

The Cove is encircled by a 17.7 km one way motor nature trail known as the Loop Road (Figure 2). Two gravel roads, Sparks Lane and Hyatt Lane, cross the Cove from north to south. Two "primitive" roads, Rich Mountain Road and Parsons Branch Road provide alternative routes out of the Cove. Laurel Creek Road is the only paved access to and from the Cove.

Elevations within the Cove range from 522 to 600 m. Geologically, the Cove is a dolomite-limestone "window" surrounded by ridges composed of older metamorphic rock. Limestone areas such as Cades Cove and White Oak Sink are important rare plant habitats within GSMNP (Bratton 1979b). Abrams Creek is the primary stream flowing through Cades Cove. Portions of this stream have been channelized in recent history. In 1974 it was fenced along the majority of its length in the Cove to exclude livestock.

A wide diversity of flora and fauna are found in Cades Cove. The open fields consist of fescues (Festuca spp.), orchard grass (Dactylis spp.), timothy (Phleum spp.), red top grasses (Agrostris spp.), and red and ladino clovers (Trifolium spp.). The wooded areas are composed primarily of mixed hardwoods, including several species of oak (Quercus spp.), maple (Acer spp.), hickory (Carya spp.), black cherry (Prunus serotina), and yellow poplar (Liriodendron tulipifera). Some of the farmsteads have been reclaimed naturally by stands of white pine (Pinus strobus), Virginia pine (P. virginiana) and pitch pine (P. rigida), with understories of hemlock (Tsuga canadensis). Common understory species include serviceberry (Amelanchier laevis), mountain laurel (Kalmia latifolia), rhododendron (Rhododendron spp.), blueberries (Vaccinium spp.), and huckleberries (Gaylusaccia spp.).

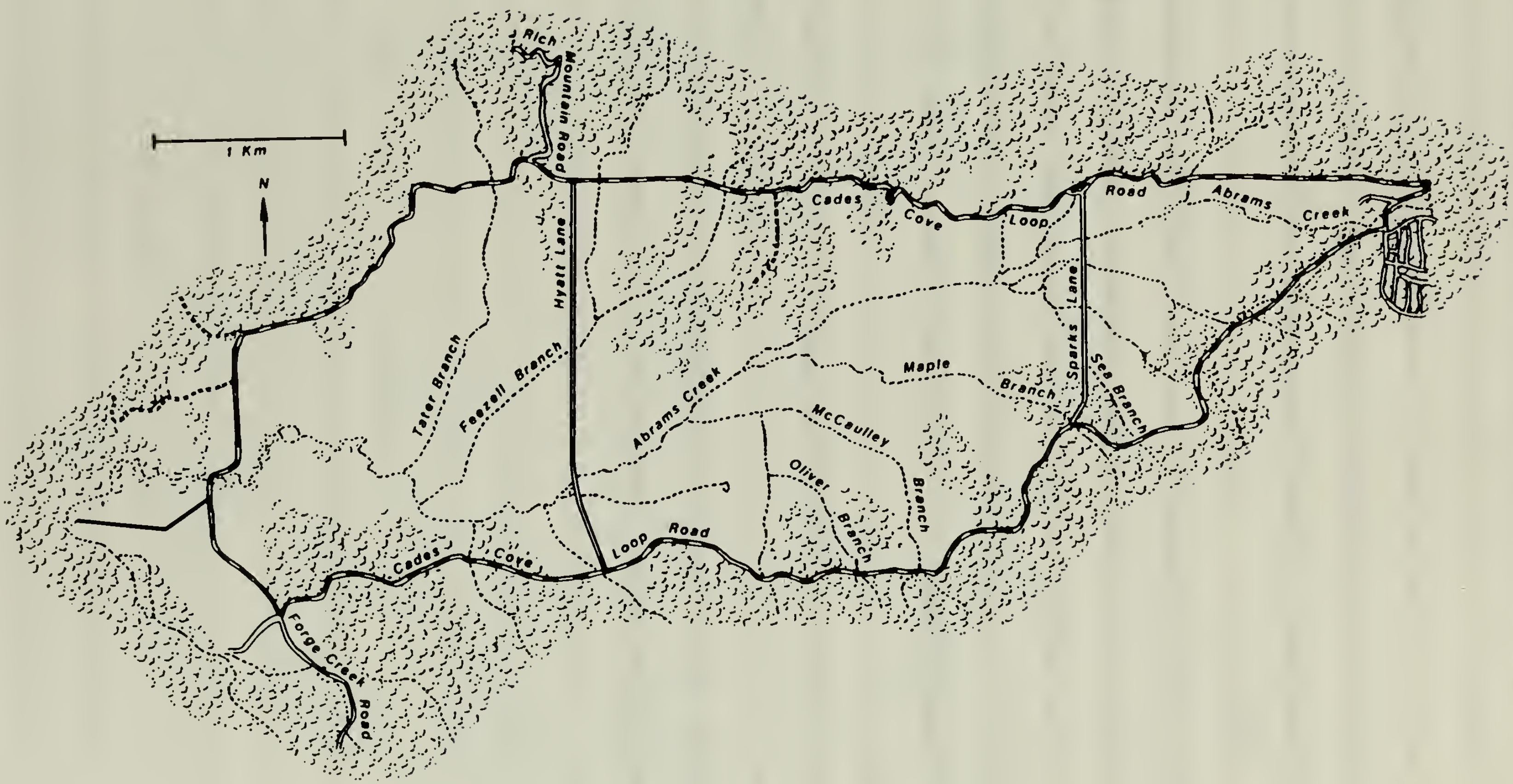

Figure 2. Map of the study area, Cades Cove, Great Smoky Mountains National Park.

A distinct browse line is evident throughout the Cove, primarily due to the impacts of cattle and deer (Bratton 1979a). Deer utilization of wooded areas resulted in a reduced ratio of deciduous stems to coniferous stems. In areas browsed by deer, oak saplings were uncommon, and dogwood (Cornus florida) were much reduced. There is a noticeable lack of redbud (Cercis canadensis) in Cades Cove, possibly reflecting impacts from deer browsing (Bratton 1979a).

Over fifty-nine species of mammals occur within GSMNP (Linzey and Linzey 1971). Other than white-tailed deer, additional large mammals occasionally using the Cove include black bears (Ursus americanus) and wild hogs (Sus scrofa). Additional mammalian species which inhabit the Cove include raccoon (Procyon lotor), bobcat (Lynx rufus), gray fox (Urocyon cinereoargenteus), red fox (Vulpes vulpes), striped skunk (Mephitis mephitis), and others.

Within the last 5 years, coyotes (Canis latrans) have become inhabitants of Cades Cove. Their impacts on the Cove deer herd are as yet undetermined. In addition to the inhabitation by coyotes, the river otter (Lutra canadensis) has recently been reintroduced by Park management into the Abrams Creek system at the western end of the Cove.

Methods and Materials

Deer were primarily censused using the nighttime roadside count method. This technique was first used in Cades Cove by Fox and Pelton (1973), and Kiningham (1980) provides a detailed description of the methodology. Basically, the technique involves driving the Loop Road and selected side roads and recording all deer observed.

For the present study, all fields and wood lots were sequentially numbered (Figure 3), and the number of deer observed in each field or woodlot was recorded. Hand-held spotlights (300,000 candle power) and binoculars (7 x 50) were used to ensure that a maximum number of deer were observed. Nighttime roadside counts were conducted bi-weekly, and the entire Cove was surveyed in most instances. Fields in which visibility was impaired by fog were deleted from that particular count. Counts were not conducted during heavy rain.

Roadside counts also were conducted at dawn or dusk each week to obtain information on adult sex ratios, productivity (fawn-at-heel counts), and ratios of tagged to untagged deer. Deer were counted only if they were within 137 m of the road to ensure accurate identification of the sex and to determine if a deer was tagged. An ocular range finder was used to determine if a deer was within 137 m, and binoculars or a spotting scope (15-60x) were used to identify the sex and tagged deer.

For the purposes of the roadside counts at dawn and dusk, deer were considered to be tagged only if they had a red roto ear tag (Nasco, Ft. Atkinson, WI) or a radio collar. Deer with brown or metal ear tags from previous years were considered to be untagged during these counts. Only antlered deer were considered to be males, and only deer with spots were considered to be fawns. The sex of fawns was not determined.

All data collected from counts were entered into database files using a dBase II program on an IBM Personal Computer. Data were then transferred to the University of

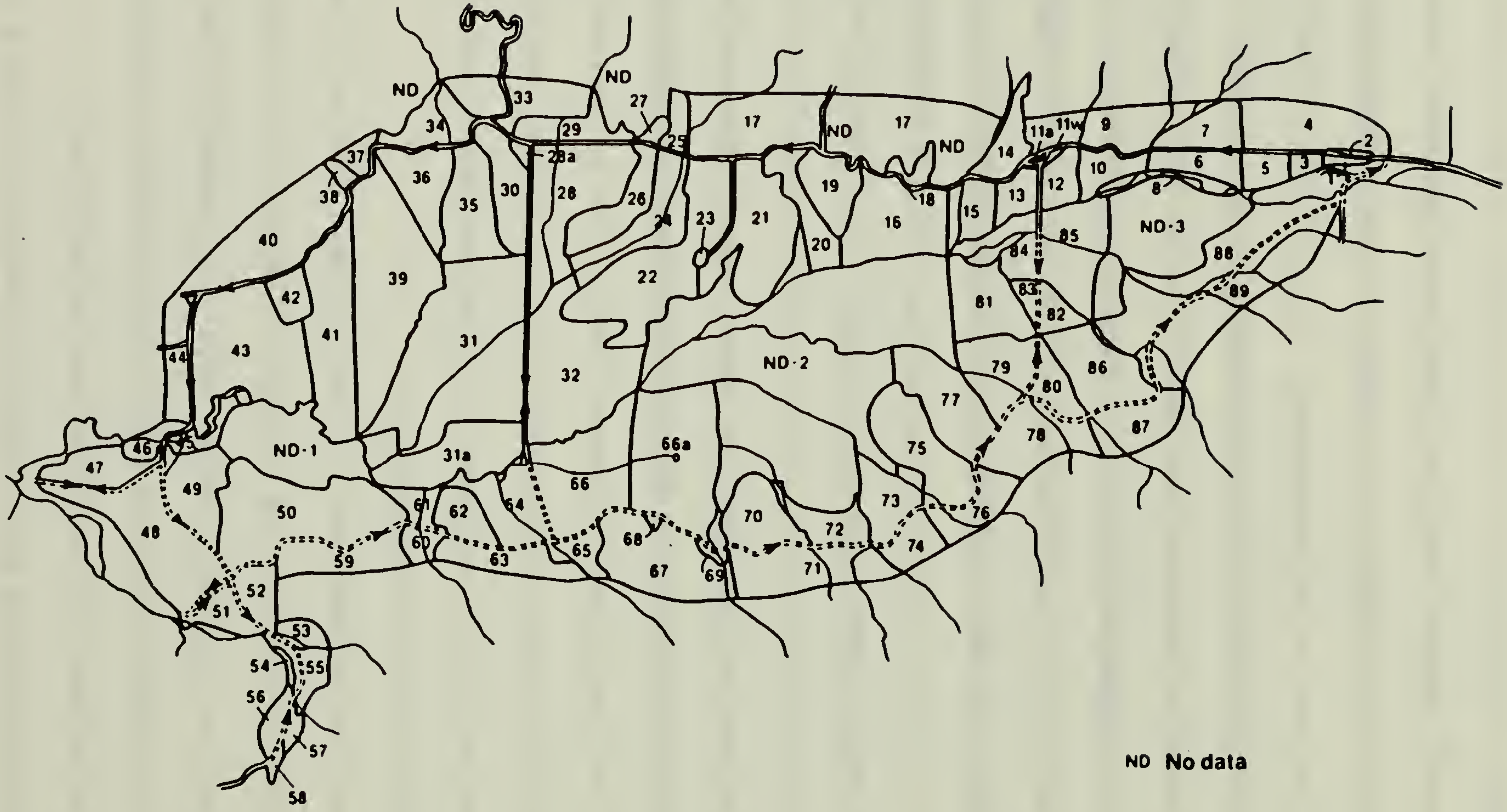

Figure 3. Field numbers used to record deer observations during roadside counts (reprinted from Kiningham 1980).

Tennessee IBM 3081 for statistical analysis using the Statistical Analysis System (SAS). SAS procedures T-TEST and General Linear Models (GLM) were used to compare densities between years and among seasons (SAS 1982b). Least-squares means (LSMEANS) were analyzed to detect differences among groups of means; LSMEANS calculate the expected class means for a balanced design (SAS 1982b).

To allow meaningful comparisons to previous studies, seasons were identical to those defined by Kiningham (1980): 1) Fall-September, October, November; 2) Winter - December, January, February; 3) Spring - March, April, May; 4) Summer - June, July, August.

Population estimates were made using 2 techniques: 1) Nighttime roadside counts (Fox and Pelton 1973, Kiningham 1980), and; 2) The mark-recapture method or Peterson-Lincoln index (Seber 1973, Tanner 1978). Density estimates derived from nighttime roadside counts were determined by dividing the number of deer observed by the total area surveyed.

The mark-recapture technique requires that a portion of a population be captured and marked so that they can be identified, and released back into the population. In subsequent samples, animals must be recaptured in some manner, and the proportion of marked to unmarked animals in the sample estimates the proportion in the population, allowing for estimates of the population size (Tanner 1978).

In the present study, red roto ear tags or radio collars were used to mark deer during capture samples. Dawn or dusk counts were used to "recapture" deer simply by reobserving them. Since fawns were not darted during the late summer or early fall, they were not included in the "unmarked" cohort.

The mark-recapture population estimates were accomplished similarly to the method described by Rice and Harder (1977). Dawn and dusk counts for each month were combined to provide a monthly marked:unmarked ratio.

The monthly population estimate was calculated using the equation

$$N_i = \frac{(M_i + 1)\ (C_i + 1)}{(R_i + 1)} - 1 \quad \text{(Chapman 1952),}$$

where:

N_i = estimate of the population, N_1 for sample i;

M_i = number of previously marked deer in the population;

C_i = number of deer (excluding fawns) observed in sample i;

R_i = number of marked deer (recapture) observed in sample i.

The final population estimate is equal to the average of the individual estimates:

$$N = \frac{N_i}{K},$$

where K is equal to the number of samples. The standard error of N was calculated using the equation

$$SE = \frac{1}{K(K-1)} \sum_{i=1}^{K} (N_i - N)^2 \quad \text{(Chapman 1952)}$$

RESULTS AND DISCUSSION

Population Size

Thirty-nine nighttime roadside counts were conducted from 13 July 1983 to 2 November 1984. A total of 8,060 deer were observed in 20,983 ha sampled for an overall estimated density of 0.38 deer/ha (2.63 ha/deer). Seasonal densities ranged from 0.20 deer/ha (5.0 ha/deer) in winter to 0.55 deer/ha (1.82 ha/deer) in spring (Table 1). The lowest observed density was 0.05 deer/ha on 31 January 1985 and the highest was 0.76 deer/ha on 27 March 1984.

Analysis of variance demonstrated that average densities varied significantly between seasons ($P<0.001$). Average observed densities during spring were significantly

Table 1. Seasonal densities of white-tailed deer observed in Cades Cove, GSMNP, 1983-1984.

Season	Year	No. Counts	No. deer observed	No. ha surveyed	Deer/ha
Summer	83	7	1289	3254.65	0.40
Summer	84	6	1412	3866.73	0.37
Fall	83	10	1395	3775.99	0.37
Fall	84	4	1093	2279.42	0.48
Winter	83/84	6	835	4079.56	0.20
Spring	84	6	2036	3726.97	0.55
Total		39	8060	20983.32	0.38

Table 2. Least squares means (LSMEANS) of seasonal densities of white-tailed deer observed by spotlight count in Cades Cove, GSMNP, 1983-84.

Season	LSMEAN (deer/ha)	Prob>T I/J	Ho: LSMEAN (I) = LSMEAN (J) 1	2	3	4
Summer	0.38	1	---	0.7270	0.0077	0.0194
Fall	0.40	2		---	0.0034	0.0345
Winter	0.20	3			---	0.0001
Spring	0.53	4				---

greater than all other seasons, and densities observed during winter were significantly lower than spring, summer, or fall (Table 2).

Mark-recapture population estimates were calculated from data collected during 63 dawn/dusk counts, 47 during the pre-removal period and 16 during the post-removal period. Data from all dawn/dusk counts conducted during each month were compiled into one count and monthly population estimates were calculated (Table 3). Monthly estimates during the pre-removal period ranged from 430 to 835 with an average of 576 deer. The approximate 95% confidence interval for the pre-removal period was 511 - 640 deer. The average population estimate during the post-removal period was 571 deer (95% confidence interval = 434-707).

The population estimates derived from the mark-recapture technique do not include fawn cohorts, and thus are underestimates for those months in which fawns are observed. A conservative estimate of the number of fawns in the population from August through November can be derived from fawn-at-heel counts. Sex ratio counts indicated that females comprised 58% of the non-fawn population; therefore, of 576 deer in the population, about 334 were does. Fawn-at-heel counts for the study averaged 19.2 fawns:100 does. Thus, a conservative estimate of 64 fawns may be added to the population estimate of 576 resulting in a total population estimate of 640 deer for the latter part of 1984.

The spotlight count and mark-recapture estimates both provided reasonable estimates of the Cove deer population. However, whereas nighttime roadside counts demonstrated significant seasonal variation in density estimates ($P<0.001$), mark-recapture estimates were not significantly variable ($P=0.606$). This apparent discrepancy between the 2 techniques could be due to several factors. First, deer may actually be moving in and out of Cades Cove. This possibility is suggested by the seasonal variation observed in the spotlight counts. For population estimates of the beginning of a sampling period, the mark-recapture technique is not affected by emigration or mortality as long as marked and

Table 3. Monthly population estimates calculated by the mark-recapture technique.

Month/Year	No. tagged in population (M_i)	Total No. observed (C_i)	No. tagged deer observed (R_i)	N_i[a]
Pre-removal				
Dec 83	45	185	11	712
Jan 84	46	100	8	526
Feb 84	45	108	5	835
Mar 84	45	238	17	610
Apr 84	50	231	18	622
May 84	54	158	14	582
Jun 84	62	101	11	535
Jul 84	71	180	24	520
Aug 84	80	132	24	430
Sep 84	89	109	16	581
Oct 84	92	93	18	459
Nov 84	94	88	16	496
Post-removal				
May 85	78	129	19	512
Jun 85	78	86	8	763
Aug 85	78	134	18	560
Sep 85	78	33	5	447

$$^{a}N_i = \frac{(M_i + 1)\,(C_i + 1)}{(R_i + 1)} - 1$$ (Chapman 1952).

unmarked deer are equally likely to disperse or die; we assumed that this was true. Therefore, the mark-recapture estimates do not rule out the possibility of seasonal movements even though there was no detectable seasonal variation in the estimates.

On the other hand, a more likely explanation to the seasonal discrepancy between the two techniques is that deer are not moving to and from the Cove, but merely changing their habitat utilization patterns between seasons. Radio telemetry data did not document any dispersals from the Cove during this study. Seasonal differences in habitat utilization by deer would not greatly affect mark-recapture population estimates since marked and unmarked deer have equal probabilities of being observed. However, differences in habitat utilization would affect spotlight count estimates. Greater utilization of woodlots by deer in winter would result in lower observed densities because of reduced visibility in wooded areas. Telemetry data indicated that deer were likely to be located in wooded areas on clear cold nights in winter. In the same manner, greater utilization of fields by deer in spring would result in higher observed densities. McCullough (1982) found that changes in deer utilization of habitats was the major factor affecting spotlight count estimates in Michigan.

The mark-recapture method of estimating populations is generally considered valid only for closed populations; that is, no recruitment, immigration, mortality or emigration may occur during the sampling period. However, if one is attempting to estimate the population size at the beginning of the sampling period, the restrictions concerning mortality and emigration may be relaxed as long as marked and unmarked animals are equally affected (Tanner 1978, Davis and Winstead 1980); this was assumed to be true in the present study. The assumption of no recruitment was met in this study by not including fawns in counts, and by establishing sampling periods from December to November. Fawns did not appear in the population until about July 1 and were distinguishable from does through November. Immigration into the Cove was assumed to be negligible, though no data exist to support this assumption.

Mark-recapture estimates also assume no gain or loss of marks from the population. Throughout the study, deer were being captured and marked, and therefore this assumption was violated in principle. However, the additions and losses of marks were monitored, and the number of marked deer assumed to be in the population (M_i) was revised monthly and population estimates re-calculated monthly to reduce the bias of the estimate.

The final assumption of the mark-recapture technique is that marked and unmarked deer must be equally "re-catchable". Since observations of marked deer during the dawn/dusk roadside counts were considered to be the "recaptures", we assumed that this restriction was met. The different methods employed in the initial capture (free-range darting) and subsequent "recaptures" (observations during counts) of deer made it more likely that an unbiased recapture sample was obtained (Tanner 1978), since some marked deer were difficult to capture by darting a second time.

Since mark/recapture population estimates yield an estimated number of animals in the population, the effective area used by the population must be determined in order to derive density estimates. Previous studies (Kiningham 1980 and others) have used 977 ha as the effective area of use by white- tailed deer in Cades Cove. In our study, telemetry data indicated that deer used substantially more area than 977 ha. By connecting the outer points of home range boundaries (Figure 4) we estimated the effective area of use to be 2,454 ha.

Assuming that the effective use area is 2,454 ha, then population and density estimates derived by spotlight counts and mark/recapture estimates yield extremely variable results (Figure 5). On one hand, mark/recapture estimates, which calculate an absolute population number, yield densities which are low compared to spotlight counts. On the other hand, spotlight counts, which estimate densities, yield high population estimates since it is assumed that the density of deer in the observation area is the same throughout the area of use. It is likely that neither of these situations is totally accurate.

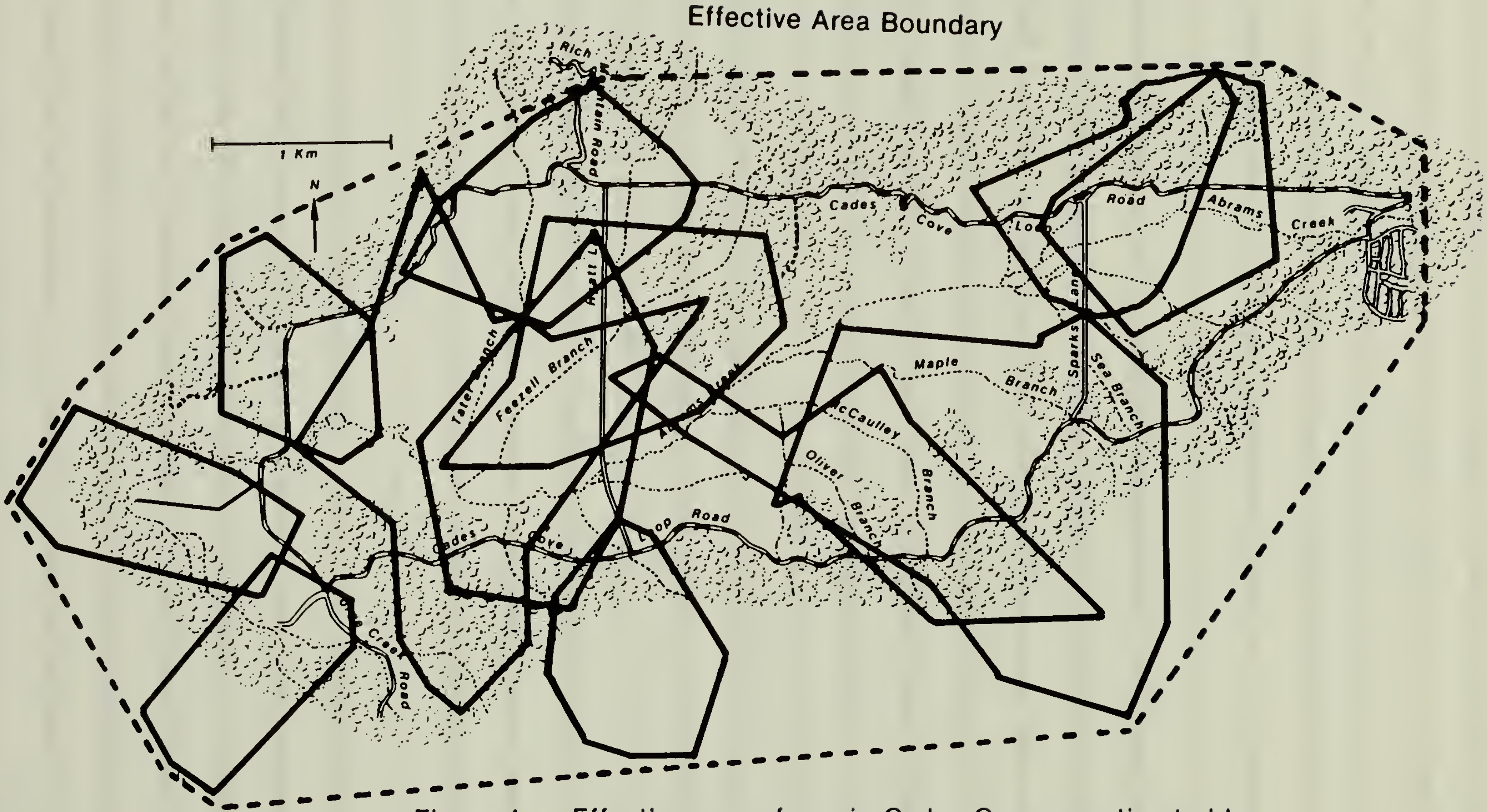

Figure 4. Effective area of use in Cades Cove as estimated by boundaries of annual home ranges of radiocollared deer.

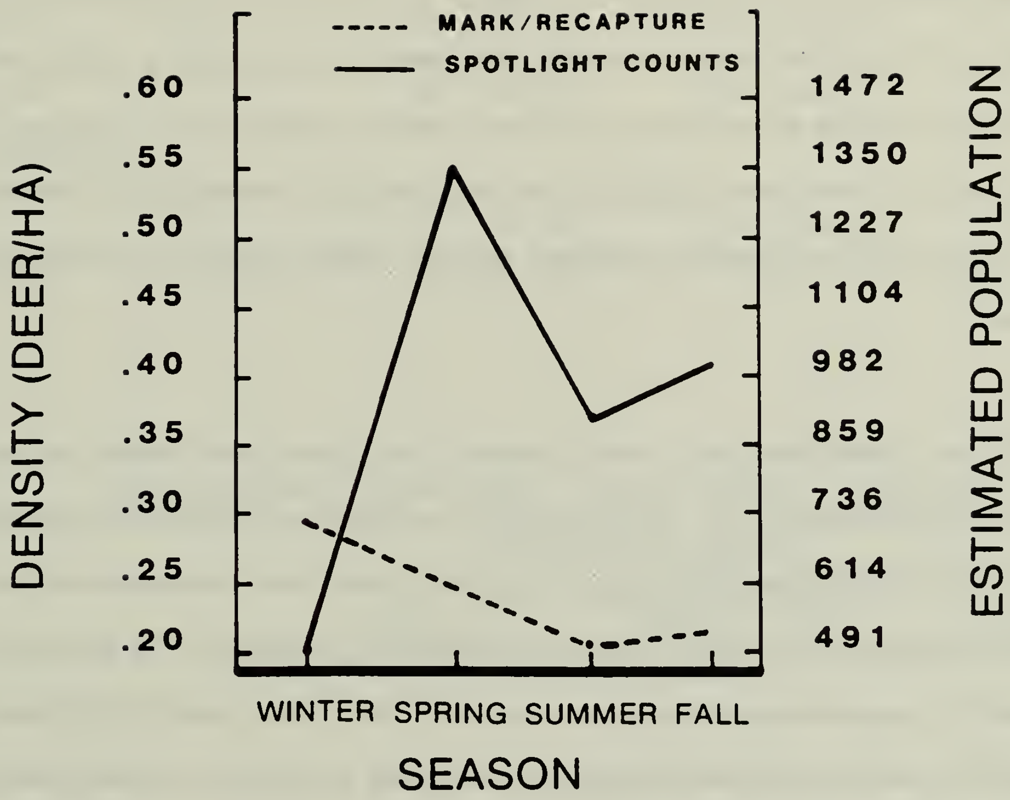

Figure 5. Seasonal density and population estimates derived by roadside spotlight counts and mark/recapture population estimates.

Deer in Cades Cove heavily utilize the field areas, especially during spring when the highest densities are observed. Therefore, the field areas contain the highest concentrations of deer. However, they also utilize the wooded areas extensively, and in some cases, more frequently than fields.

Of the 2 techniques, the mark/recapture estimates may be more precise since they are relatively stable seasonally (Figure 5). It is likely, however, that the population is not homogeneously dispersed throughout the effective area, but is concentrated around the field areas, and less dense in the wooded areas away from the Cove. The very high densities observed during early spring probably represent a time when a majority of deer are utilizing the field areas, and spotlight counts may provide a reasonable estimate during this time, if the data are stratified between general habitat types (i.e. field areas and wooded areas).

<u>Sex Ratio</u>

Estimates of adult sex ratio were calculated from dawn/dusk counts conducted in August and November each year. These particular months were selected for two reasons. First, from a behavioral standpoint, these two months have been recommended as times when bucks and does are equally likely to be observed (Michael 1970, Downing et al. 1977). Second, comparisons with previous studies in the Cove (Burst and Pelton 1978, Kiningham 1980) would be more meaningful, since their estimated sex ratios were based on observations during these months.

The adult sex ratios (buck:doe) observed during the present study ranged from 49:100 to 80:100 (Table 4). The overall adult sex ratio observed was 72.3:100. Considering only the pre-removal period (1983 and 1984), sex ratios were not significantly different between years ($G=0.312$; $P>0.5$). There also was no significant difference between the pre- and post-removal periods ($G=0.307$; $P>0.5$).

Considering the history of deer removals conducted in Cades Cove from 1981 to 1984 (Table 5), in which females were removed from the population at a much greater rate

Table 4. Adult sex ratios observed during dawn/dusk counts in Cades Cove, GSMNP, 1983-1985.

Month/ Year	No. of Counts	No. of Males(%)	No. of Females (%)	Ratio
Pre-Removal				
Aug 83	5	70 (41.7)	98 (58.3)	71:100
Nov 83	2	33 (44.6)	41 (55.4)	81:100
Total 83	7	103 (42.6)	139 (57.4)	74:100
Aug 84	4	59 (44.7)	73 (55.3)	81:100
Nov 84	3	29 (33.0)	59 (67.0)	49:100
Total 84	7	88 (40.0)	132 (60.0)	67:100
Post-Removal				
Aug 85	5	59 (44.0)	75 (56.0)	79:100

Table 5. Deer removals from Cades Cove, GSMNP, 1981-84.

	No. Deer Removed		
Date	Males (%)	Females (%)	Total
February 1981	3 (5.9)	48 (94.1)	51
December 1981	2 (3.5)	55 (96.5)	57
December 1982	14 (19.4)	58 (80.6)	72
December 1984	20 (19.8)	81 (80.2)	101
TOTAL	39 (13.9)	242 (86.1)	281

than males, it was expected that some change in sex ratio would be observed between studies. The sex ratio observed during 1983-84 (70.5:100) reflected a greater proportion of males than observed during 1978-79 (33.4:100; Kiningham 1980), but not during August 1977 (90.9:100; Burst and Pelton 1978). It is difficult to explain the disparity between 1977 and 1978-79, but the increase in the male proportion of the population from 1978-79 to 1983-84 (25% to 41%) likely reflected the emphasis on removing does from the population from 1981-83.

The observed change in the male proportion from 1984 (40%) to 1985 (44%) was rather small, and perhaps not as great as was expected. However, in a theoretical population of 500 deer, with 40% bucks (200), a removal of 10 males and 90 females would result in a population of 190 males (47%) and 210 females (52%). This small difference would be difficult to detect with the relatively small sample sizes we observed.

The above results must be interpreted with caution because several factors could affect observed sex ratios. For example, Kiningham (1980) observed a decrease in the proportion of bucks from August to November and speculated that dispersal by bucks during that time accounted for this decrease. In the present study, a similar shift in sex ratio was observed in 1984, but not in 1983 (Table 4). It is impossible at this point to explain these observations, but dispersal of bucks from the Cove was not documented in the telemetry study, though the sample was small.

Other factors which may affect sex ratios include differential mortality rates of males and females, and the yearly recruitment of young males and females into the adult population. Both telemetry data and incidental mortality observations indicated that males were more susceptible than females to mortality factors. All radiocollared deer which died during the study ($n=5$) were bucks, and about 2/3 of all other carcasses found were bucks.

The effect of recruitment on the sex ratio in Cades Cove is unknown at this time. However, based on the premise that the Cove deer herd is a dense deer population with a low reproductive rate, it might be expected that the sex ratio of fawns would favor males (Verme 1983). There were no data available in the present study to test this relationship.

Even given the constraints mentioned above concerning the effects of dispersal, mortality, and recruitment on sex ratios, the available data indicate that the adult sex composition of the Cades Cove deer herd has shifted toward males in response to the disproportionate removal of females from the Cove from 1981-1984.

Productivity

The majority of reproductive information collected on deer in Cades Cove has consisted of fawn:doe ratio counts (Burst and Pelton 1978, Kiningham 1980). Also, some reproductive tracts were collected from deer, most of which died as a result of drug overdoses during immobilization.

In the present study, an intensive effort was made to obtain information related to reproduction. When deer were immobilized, the reproductive condition of females (pregnant, lactating, number of fawns in area, etc.) was determined. Reproductive tracts of females were collected when possible, and the ovaries and uteri were analyzed to assess reproductive performance. Age ratios of capture samples were also analyzed to elucidate information concerning recruitment of fawns into the deer herd.

Fawn to doe ratios were calculated from dawn/dusk roadside counts conducted August through October each year (Table 6). Although fawns were observed in July, these data were not included in the estimates, primarily because fawns remain isolated and separated from their mother and siblings much of the time during the first month of life (Jackson et al. 1972). Fawns were first observed in Cades Cove in late June or early July and telemetry data indicated that radiocollared does and their fawns were not observed together much of the time during the summer.

Fawn to doe ratios observed in the present study ranged from 18 to 20 fawns:100 does (Table 7). Compared to previous studies in Cades Cove, these ratios are low. Only the estimate in 1979 (8.4:100; Kiningham 1980) is lower. However, it should be noted that

Table 6. Fawn to doe ratios observed in Cades Cove, GSMNP during dawn/dusk counts conducted during August through November, 1983-85.

Month/Year	No. of Counts	No. Does observed	No. Fawns observed	Ratio (Fawn:Doe)
Aug 83	5	98	19	19.4:100
Sep 83	4	88	17	19.3:100
Oct 83	2	57	12	21.1:100
Tot.83	11	243	48	19.8:100
Aug 84	4	73	7	9.6:100
Sep 84	4	58	17	29.3:100
Oct 84	3	63	11	17.5:100
Tot.84	11	194	35	18.0:100
Aug 85	5	75	14	18.7:100
Sep 85	3	15	4	26.7:100
Tot.85	8	90	18	20.0:100

Table 7. Fawn to Doe ratios observed in Cades Cove, GSMNP, 1977-1985.

Year	Ratio (Fawn:Doe)	Source
1977	49.5:100	Burst and Pelton (1978)
1978	27.9:100[a]	Kiningham (1980)
1979	8.4:100[a]	Kiningham (1980)
1983	19.8:100	Present Study
1984	18.0:100	Present Study
1985	20.0:100	Present Study

[a] Includes observations made in July.

the estimates in 1978 and 1979 include observations during July, and may be underestimates. The low productivity suggested by the fawn to doe ratios was also suggested by few observations of twins and triplets. Minimum numbers of twins observed in the Cove ranged from 3 in 1983 and 1984 to 5 in 1985. One set of triplets was observed in 1984. These results should be interpreted with caution, however, since fawn siblings often remain separated from each other, especially during the first 3 to 6 weeks of life (Downing and McGinnes 1969, Jackson et al. 1972, White et al. 1972).

Reproductive data obtained from immobilized female deer are presented in Table 8. There was no evidence during the study that fawns reproduced. Reproductive data collected from 1980 to 1982 were relatively sparse; however, during 1980 all seven adult females examined were pregnant or lactating. Information collected during 1983 and 1984 indicated that productivity was low for both years, with only 32% of adult females pregnant or lactating in 1983, and 72% in 1984.

Reproductive information was also derived from 15 reproductive tracts collected from 1980 to 1985 (Table 9). Although the sample size is small, the information nevertheless provides some indication of the reproductive performance of the Cades Cove deer herd. Counts of fetuses were made from 8 reproductive tracts that were collected in late winter or spring. The remainder of the tracts were collected during the rut period of 1984. Ovaries from these tracts were examined and interpreted to provide indirect information on reproduction.

Teer et al. (1965) pointed out that ovaries collected during the rut period may or may not show evidence of ovulation. However, they demonstrated that reproductive performance could be estimated by multiplying the ovulation rate (number of corpora lutea divided by the number of deer that ovulated) by the fertilization rate (percentage of ova fertilized) and the conception rate (percentage of females with corpora albicantia in their ovaries). Following parturition, corpora lutea of pregnancy begin to degenerate into yellowish-brown pigmented structures known as corpora albicantia. These structures

Table 8. Reproductive data obtained from immobilized female deer in Cades Cove, GSMNP, 1980-84.[a]

Year	Season	No. Immobilized	No. Pregnant	No. Lactating	% Pregnant or Lactating
			Yearlings		
1980	Summer-Fall[b]	4	0	0	0.0
1981	Winter	0	0	0	0.0
1983	Summer-Fall	6	0	0	0.0
1984	Summer-Fall	1	0	0	0.0
Total		11	0	0	0.0
			Adults		
1980	Summer-Fall	7	2	5	100.0
1981	Winter	3	3	0	100.0
1983	Summer-Fall	19	0	6	31.6
1984	Summer-Fall	18	6	7	72.2
Total		47	11	18	61.7

[a] No reproductive data was collected in 1982
[b] Summer-Fall season includes June through September.

Table 9. Reproductive information obtained from reproductive tracts collected in Cades Cove, GSMNP, 1980-85.

Date	Deer No.	Age	No. Corpora Lutea	Corpora Albicantia	No. Fetuses
3 Apr 80	307	2.0	-	-	1
2 May 80	311	-	-	-	2
14 Feb 81	1083	7.5	-	-	1
14 Feb 81	1084	2.5	-	-	2
15 Feb 81	1048	1.5	-	-	1
16 May 84	51684	2.0	0	-	0
28 May 84	032708UT	2.0	-	-	1
3 Dec 84	120384	-	0	Y	-
7 Dec 84	1207841	3.5	0	Y	-
7 Dec 84	1207842	3.5	1	Y	-
10 Dec 84	1210842	2.5	0	N	-
10 Dec 84	1210843	2.5	0	N	-
12 Dec 84	1212841	1.5	1	?	-
12 Dec 84	1212842	2.5	1	N	-
28 Feb 85	33 Red	4.5	0	-	0

persist in the ovaries at least eight months, and thus provide evidence of reproduction from the previous year (Cheatum 1949). Some researchers have published evidence which indicates that counts of corpora albicantia overestimate ovulation rates (Golley 1957, Teer et al. 1965). However, Teer et al. (1965) believed the presence or absence of corpora albicantia in the ovaries was at least a reliable indicator of whether or not a doe had given birth the previous year.

Data on fertilization rates in the Cades Cove deer herd are lacking. However, Teer et al. (1965) observed an average fertilization rate of 88% in Texas, and their figure was used to calculate reproductive performance based on ovarian analysis. The examination of ovarian structures in 7 sets of ovaries collected during the rut of 1984, indicated an ovulation rate of 1.0, and conception rate of 0.5. Therefore, the reproductive performance of adult does in Cades Cove based on ovarian analysis was 0.4 embryos per doe.

Another estimate of reproductive performance may be obtained by multiplying the percentage of females lactating by the average litter size. The average number of fetuses in the reproductive tracts collected from 6 pregnant does was 1.3. Assuming that 1.3 was the average litter size for Cades Cove deer, and, based on few observations of twins and triplets that may be a high estimate, the reproductive performance of adult does ranged from 0.4 to 1.3 fetuses per doe. The overall reproductive performance of adult does was 0.8 fetuses per doe (Table 10). Although the sample sizes are small and should therefore be interpreted cautiously, comparison with other areas indicates a low reproductive rate in Cades Cove. The data collected during 1983 and 1984, when reproduction was more intensively monitored, demonstrated a pooled reproductive performance of 0.7 fawns per doe. Teer et al. (1965) observed 1.08 embryos per adult female in Texas. In the midwest agricultural region, 97% of adult does were pregnant with 1.91 embryos per doe (Gladfelter 1984). In middle and west Tennessee, mean number of fawns for 2 and 3-year old females was 1.65 and 1.87, respectively (Torgerson and Porath 1984).

Table 10. Reproductive performance of adult does in Cades Cove, GSMNP based on percentage of females pregnant or lactating, and assuming an average litter size of 1.33.

Year	No. of adult females	% Pregnant or Lactating	Fetuses per Doe
1980	7	100	1.3
1981	3	100	1.3
1983	19	31.6	0.4
1984	18	72.2	1.0
Total	47	61.7	0.8

Several investigators have shown that reproductive rate in white-tailed deer is influenced primarily by quality of diet (Morton and Cheatum 1946, Cheatum and Seveninghaus 1950, Verme 1969, and others). Both Teer et al. (1965) and McCullough (1979) observed that deer productivity decreased with increasing density, and related the lowered reproduction to reduced nutritional availability caused by dense deer herds overgrazing the range. In a Michigan enclosure, reproductive rate for yearling and adult females dropped from 1.95 to 0.32 embryos per doe at densities of 0.02 and 0.41 deer/ha, respectively (McCullough 1979). Teer et al. (1965) observed reproductive rates of 0.93 embryos/adult doe at an estimated density of 0.44 deer/ha.

The Cades Cove deer herd was found to be densely populated in the present study, and has apparently remained stable in size since 1979. Although browse is lacking in the wooded areas of Cades Cove (Bratton 1979a), the quality of diet available to deer in alternative food resources (hay fields, hard mast, etc.) is largely unknown. However, it is likely that the combination of a concentrated density of deer, and resultant competition for the available food resources has resulted in the observed low reproductive rate during this study.

Hard mast in the form of acorns is an important food source for white-tailed deer in the southern Appalachians, especially in the fall and winter when it has been found to constitute an average of 76% of rumen contents during years of mast abundance (Harlow et al. 1975). French et al. (1986) found that acorns comprised 50% of rumen contents during the fall in Tellico Wildlife Management Area. They also found black cherry fruits to be an important fall food component.

Does that are in good nutritional condition entering the breeding season may breed earlier and produce more offspring than those in poor condition (Verme 1969). In areas such as Cades Cove, in which the deer population is dense and there are few alternative high energy food sources (e.g. agricultural crops), acorn crop fluctuations may significantly affect deer reproduction.

Apparently, fawn-at-heel counts were not sensitive to the observed changes in lactation rates in this study. Even though the percentage of lactating females changed from 32% in 1983 to 72% in 1984 ($G=6.25$, $P<.05$), the observed fawn to doe ratios remained nearly the same (19:100 in 1983, 18:100 in 1984). Fawn-at-heel counts are used as an index to productivity in many areas (Teer et al. 1965, Downing et al. 1977). However, for these counts to accurately assess productivity, fawns must be equally observable to does. During the first month of life this is certainly not the situation, since fawns remain inactive most of the time, and are usually sought out by the doe for nursing sessions (Jackson et al. 1972). Even during the second month of life fawns are only half as active as adults (Jackson et al. 1972). Downing et al. (1977) found that counts of fawns and does only approached expected ratios in late fall (October through December), but fawns at this time were sometimes difficult to distinguish from yearlings.

It is readily apparent that fawn-at-heel counts have little utility in accurately assessing productivity in Cades Cove. If the level of productivity is deemed an important priority in monitoring the condition of the Cades Cove deer herd, it is recommended that reproductive tracts be collected when possible from deer carcasses such as road kills, drug-overdosed deer, etc. Also, yearly summer darting would allow the collection of lactation data along with other physiological parameters (e.g. blood samples for disease monitoring) to give a better overall picture of the condition of this deer herd.

<u>Fawn Recruitment</u>

Age data obtained from capture samples during summer darting and winter deer removals (Table 11) were used to evaluate the recruitment of fawns into the population. Only female yearlings and adults were used in the analysis for 2 primary reasons. First, during winter deer removals, efforts were directed at does, and adult bucks were avoided, thus biasing the age ratios of males. Secondly, yearling and adult females are not distinguishable by sight in the field, and were assumed to be equally capturable.

Table 11. Sex and ageclass distribution of white-tailed deer captured in Cades Cove, GSMNP, 1980-84.

		Males			Females		
Year	Season[a]	Fawns	Yearlings	Adults	Fawns	Yearlings	Adults
1980	Summer/ Fall	0	2	9	0	5	8
1980/ 81	Winter	0	7	9	0	5	39
1981/ 82	Winter	2	1	2	1	11	41
1982	Summer/ Fall	0	7	18	0	2	6
1982/ 83	Winter	1	1	18	1	9	30
1983	Summer/ Fall	0	13	37	0	12	35
1984	Summer/ Fall	0	4	27	0	2	23
1984/ 85	Winter	4	8	5	8	8	60

[a] Summer/Fall season extends from 1 June to 30 November; Winter season was associated with deer removals conducted during these years.

The percentage of yearlings in the female capture samples ranged from 8 to 38% and was 18% for the entire sample period. The low percentage of yearlings captured in 1984 was notable because it tended to support the observation of a lowered reproductive rate in 1983. Although a similarly low frequency of yearlings was obtained in the winter of 1981, the deer removal occurred at a time (February) when yearlings are easily misclassified as 2 year-olds; it is possible that several deer were misclassified, thus skewing the percentage of yearlings downward.

Comparisons of yearling female frequencies to productivity rates allowed us to estimate the mortality rate of female fawns during their first year of life. However, it should be cautioned at the outset that sample sizes are small, and the estimates should be considered rough.

For example, assume that the productivity rate for Cades Cove deer (yearlings and adults) during 1980-84 is 0.67 fetuses per doe. Assuming a 50:50 sex ratio of fetuses, female fawns would comprise about 25% of the female population at birth, or 34 female fawns per 100 does. The observation of 18% yearlings in the female capture sample translates into 22 yearlings for every 100 adult females, a net loss of 12 fawns (34-22) or an estimated fawn mortality rate of 35% (12/34). The estimated mortality rate would be even greater if mortality rates of adult females were known and included. For the only years in which adequate reproductive data and subsequent yearling samples were obtained (1983-84) the estimated female fawn mortality rate was 25%. These estimated mortality rates do not address fawn mortality for males, but it seems likely that male fawn mortality is as great or greater than female fawns. In Texas, young male fawns are generally more active than female fawns (Jackson et al. 1972), and also have higher mortality rates.

Mortality of fawns is influenced by several factors, including predation (Cook et al. 1971, Kie et al. 1979), density (McCullough 1979), and nutritional condition of does (Murphy and Coates 1966), which may be a function of density or other environmental factors. Several studies have indicated that fawn mortality is likely to occur early in the fawn's life. For instance, in dense herds, some does may be nutritionally unable to support their fawns and thus reject them (Verme and Ulrey 1984). Deer which were fed diets supplemented with 13%, 10% and 7% protein, experienced fawn losses of 0%, 27%, and 42% respectively (Murphy and Coates 1966). Ozoga et al. (1982) concluded that in dense herds, crowding resulted in excessive mortality to fawns of does lower in the hierarchical structure. Cook et al. (1971) documented 72% mortality of radiocollared fawns in Texas, most (93%) within the first month of life. Coyote predation and starvation/disease accounted for the majority of deaths (Cook et al. 1971).

The estimated fawn mortality rate in Cades Cove (25%) does not appear to be excessive when compared to estimates from other areas, and in fact may be a little lower than some areas. However, coupled with the low reproductive rate observed, the additional fawn mortality serves to limit the number of yearlings being added to the population. In fact, the low percentage of 1 year old deer observed in the population in 1984 (10.8%) seems to indicate the very low reproductive rate of 1983 plus mortality of fawns.

<u>Mortality</u>

Data on mortality were obtained from field observations of deer carcasses, ranger reports, and from known losses of radiocollared animals. A total of 40 carcasses were observed in 1983 and 1984 (Table 12). These data do not include mortalities due to drug overdose (SEE Drug Related Mortality) or management kills for the purposes of abomasal parasite counts. When carcasses were found, sex was determined and if possible, the cause of death was determined.

Several carcasses were found by locating congregations of turkey vultures (<u>Cathartes aura</u>) or black vultures (<u>Coragyps</u> <u>atratus</u>) and searching the surrounding area. In many instances, it was impossible to determine the cause of death of these scavenged carcasses. When predation of a deer was suspected, the surrounding area was searched for signs of struggle and evidence of predatory species. Unnatural positions of the carcass such as

Table 12. Deer mortalities and their suspected causes in Cades Cove, GSMNP, 1983-84.

Cause of Mortality	Fawn M	Fawn F	Fawn ?	Yearling M	Yearling F	Adult M	Adult F	Age Unknown M	Age Unknown F	Unknown Sex/Age	Total
Road Kill	0	1	0	0	0	1	1	0	1	1	5
Depredation											
Bear	0	0	0	0	0	1	0	0	0	1	2
Dog/Coyote	0	0	0	0	1	1	1	2	1	0	6
Unknown	1	0	0	0	0	1	0	0	1	0	3
Illegal kill	0	0	0	0	0	1	0	0	0	0	1
Sick/Euthanized	0	0	0	0	0	0	2	1	0	0	3
Disease/Parasitism	0	0	0	0	0	0	1	2	0	0	3
Hay Cutting Operations	0	0	1	0	0	0	0	0	0	0	1
Dueling Fatality	0	0	0	0	0	1	0	0	0	0	1
Unknown	0	0	2	1	1	5	0	0	1	5	15
Total	1	1	3	1	2	11	5	5	4	7	40

splayed rear legs were also helpful in determining a suspected depredation (Wade and Bowns, N.D.). Some depredations, such as bear kills were based on eyewitness accounts.

Of the 40 mortalities, 15 were of unknown cause (Table 12). Many of these carcasses were too old to allow a reasonable speculation as to the cause of death. Eleven (27.5%) mortalities were determined to be the result of depredation. Of these, 6 were determined to be killed by dogs or coyotes. Six deer were sick or injured animals that were euthanized (n=3), or died as a result of disease or parasitism. Five deer died as a result of collisions with automobiles.

Of the 30 carcasses for which sex was determined, 18 (60.0%) were males, and most of these were adults. Five carcasses were determined to be fawns. Data from radiocollared deer indicated that males were more susceptible to mortality factors than females. All 5 radiocollared deer which died during the study were males.

The results of these rather limited data on deer mortality indicate that predation is one of the major causes of death in Cades Cove, with dogs or coyotes being the major predators. No real attempt was made in this study to distinguish between a dog or coyote kill. However, observations by rangers and field personnel indicate that free-ranging dogs have become a significant problem in Cades Cove. It is suspected that most of these kills were dog related.

Domestic dogs are not generally thought to be effective predators of deer (Progulske and Baskett 1958, Marchinton et al. 1971, Perry and Giles 1971). However, in some areas they may have detrimental impacts on deer herds, especially in areas with marginal deer populations (Mech 1984). Dogs are thought to hamper deer restoration efforts in some areas of Tennessee (Nichols and Whitehead 1978). There is also some evidence that dogs are more successful preying on deer in mountainous areas (Corbett et al. 1972).

Coyote predation on deer generally involves the taking of fawns (Mech 1984). In some areas with high coyote populations, they are a major cause of fawn mortality (Cook et al. 1971, Kie and White 1985). The impact of coyotes on the Cades Cove deer population is unknown at this time. However, they probably will have more of an impact on the fawn population if the coyote population increases.

In past studies, hay mowing operations have been cited as a cause of fawn mortality in Cades Cove (Kiningham 1980). Only 1 fawn mortality related to hay mowing was documented in our study. However, another cause of fawn mortality observed in the present study indirectly involved Park visitors. In several instances, Park visitors picked up young fawns which were thought to be abandoned and transported them to the Cades Cove ranger station. The rangers would immediately return the fawns to the original site of discovery, but several of the fawns were later found dead (Eddie Wilmoth, personal communication).

Conclusions

In summary, the data on population dynamics collected in this study indicate that the Cades Cove deer population remains at a relatively dense level (0.38 deer/ha by spotlight count; 0.23 deer/ha by mark/recapture population estimates), comparable to levels observed in 1978-79 (Kiningham 1980). Density levels estimated by spotlight counts were significantly variable among seasons, with the highest densities observed in spring (0.55 deer/ha); mark/recapture population estimates were relatively stable among seasons and appear to be more reliable as a population estimate.

A sex ratio of 72 males:100 does was observed during roadside counts at dawn and dusk. Fawn-at-heel counts ranged from 18-20 fawns:100 does during 1983-85, but were considered unreliable as estimators of productivity because they did not correlate with observed changes in lactation rates of adult females. Reproductive data from capture samples in the summers of 1983 and 1984 demonstrated that 51% of adult does were pregnant or lactating, with an average reproductive rate estimated to be 0.68 fetuses/adult doe (assuming an average litter size of 1.33); there was no evidence of breeding fawns.

Analysis of age ratios (yearling and adult females) suggested that mortality of female fawns was roughly 25%; mortality of male fawns is probably at a similar or higher level. Predation was determined to be a significant (27.5%) cause of mortality for all deer, with dogs or coyotes accounting for most (6 of 11) of the kills. Deer succumbing to diseases or parasitism and road killed deer also contributed to the mortality observed.

The deer removals conducted by GRSM and TWRA were initiated to assist TWRA in its deer herd restoration efforts in East Tennessee. Recommendations for deer removal from the Cove have been made by several researchers (Burst and Pelton 1978, Dlutkowski 1985, Hastings 1986), although Kiningham (1980) believed that the best alternative was to implement intensive research on the deer population and its impacts in the Cove. The deer removals were also good policy from a public relations standpoint; deer removal was the management alternative most favored by visitors to Cades Cove (Hastings 1986).

The data collected in the present study suggest that, even with the emphasis on removing does, the deer removal efforts did not reduce the population from the levels observed in 1978-79. Though deer herd control was not an objective, the removals may have been successful in maintaining the population at the present high density. However, one question raised is whether or not the herd size would have stabilized on its own if the removals had not been conducted. Kiningham (1980) speculated that the decreasing fawn:doe ratios observed in his study indicated a stabilizing population at a high density. The data collected in our study demonstrated a very low reproductive rate in this herd, possibly reflecting this stabilizing effect in the population.

The emphasis on removing does during the deer removals clearly had one major impact on the Cades Cove deer herd: the observed sex ratio was dramatically changed from 33 males:100 does in 1978-79 (Kiningham 1980) to 72:100 in 1983-84 (this study). Though not documented in our study, production of more fawns in response to the overcrowded conditions may have contributed to the change in sex ratio (Verme 1969). The impacts of this change on the herd are unknown at this time, although there may be some disease related effects, such as increasing the spread of leptospirosis. We believe that with the inherently higher mortality rates of bucks and dispersal, the sex ratio will revert to a similar composition observed by Kiningham (1980).

Presently, the Cades Cove deer herd is a high density, relatively stable population, with low productivity. An abomasal parasite count (APC) conducted in 1983, yielded an average of 2150 for this population. According to the technique (Eve and Kellogg 1977), an APC greater than 1500 suggests that the herd is at or over carrying capacity. Eve and Kellogg (1977) suggest that other conditional indices be used in addition to the APC to assess the overall health of the herd.

In a blood chemistry study conducted in 1980-82, Dlutkowski (1985) found that the deer of the Cove exhibited elevated levels of leukocytes, indicating a response to pathologic stimuli such as disease or parasitism. An investigation of several biochemical parameters demonstrated significant seasonal variations with lower values observed during the winter months. Some parameters were consistently lower than reported values for white-tailed deer, but were not indicative of a malnourished deer herd (Dlutkowski 1985). Much of the nourishment available in Cades Cove is likely provided by the forbs and grasses present in the hay fields and pastures of the Cove.

The future status of the Cades Cove deer herd is dependent on several factors. First, future deer removals from Cades Cove appear to be unlikely, primarily because TWRA has completed its deer restoration efforts in east Tennessee and will make no further requests for deer (B. Nichols, personal communication). Without deer removals, the herd is likely to stabilize at a high density with a low rate of recruitment. McCullough (1979) feels that recruitment rates in deer are largely density dependent, and that, in relatively stable environments, density levels tend to stabilize at around the carrying capacity (k) after an original overshoot of k.

Cades Cove can probably be considered a relatively stable environment, with a reliable food resource made available by the hay fields and pastures. Although shortages of hard mast and forage may cause undernourishment during the winter months, in the past this has not resulted in lowered blood chemistry values suggestive of overall health reduction (Dlutkowski 1985).

The greatest environmentally unstable influence on the Cades Cove deer population appears to be infectious disease. Localized outbreaks of some diseases have the potential to dramatically reduce the deer population, and thus represent a factor that can result in population fluctuations (McCullough 1979). The potential impact of disease on the Cove deer herd is discussed later in this report.

Besides diseases, there appear to be 2 additional factors which may have some influence on the future of this deer population. First, habitation of Cades Cove by the coyote (Canis latrans), initially reported in May 1981, may result in its becoming a regulating force on the deer herd. Although it is unlikely that coyotes will actually reduce the size of the population, they may at least become a stabilizing influence. In some areas with dense coyote populations, significant mortality levels in fawns have been reported (Cook et al. 1971, Kie and White 1985).

A second factor likely to have influence on the deer of Cades Cove is the cattle herd. This study, as well as previous studies (Burst and Pelton 1978, Kiningham 1980) has documented the reduced utilization of cattle pastures by deer. In effect, the cattle herd has excluded deer from some of the available habitat of the Cove. Presently, cattle pastures comprise between 300 and 400 ha, more than 1/3 the available field area. One land management alternative being considered by Park management is the significant reduction or complete elimination of cattle from the Cove. If these areas are maintained as fields, then from a population dynamics standpoint, a possible result of this action will be the opening up of previously "unavailable" field areas to the deer herd, and a concomitant increase in the deer population.

MOVEMENT ECOLOGY

METHODS AND MATERIALS

Deer were immobilized during darting exercises with succinylcholine chloride. Once immobilized, they were marked with an identifying ear tag and aged. Because of the inexperience of some data collectors, it was felt that age determination to within one year was probably not reliable enough to use in statistical analyses. Consequently, ages of deer were collapsed into two major classes, less than 1.5 years (subadults) and 1.5 years and older (adults). The investigators felt deer could be reliably categorized in this manner. Selected deer were fitted with motion sensitive radiotransmitter collars (164-165 MHz; Wildlife Materials, Inc., Carbondale, IL). Adult males were fitted with radiocollars having 2 elastic stretch tubes allowing for neck swelling during the rut.

Radiotracking was accomplished with a portable receiving unit (Model LA-12; AVM), and a handheld, 2-element "H" antenna (Telonics, Inc., Mesa, AZ). In most instances, locations were made by triangulating compass azimuths from known points in the study area. The "loudest signal" method was used for determining the direction of the signal (Springer 1979). Azimuths were determined with a handheld compass, and plotted on a 1:24,000 scale U.S.G.S. topographic map of Cades Cove. In most cases, 3 to 4 azimuths were required to get an adequate "radio fix" on the location, but sometimes as few as 2, or as many as 8 azimuths were used. Depending on the time of year and time of day, deer were often visually located in open fields; these types of locations occurred early or late during the day as deer were moving from the woods to the fields, or vice versa. All locations, whether determined visually or by triangulation, were transferred to study area maps for each deer and assigned Universal Transverse Mercator (UTM) grid coordinates to facilitate data analysis. Other data collected in connection with locations included climatological data (i.e., temperature, cloud cover, precipitation), activity, and group size and classification (for visual locations).

Radiocollared deer were located at least 3 times a week and efforts were made to obtain locations at various times of the day. Radiotracking was conducted during the day or at night on an alternating weekly schedule to accomplish this goal. Twelve-hour radiotracking sessions were conducted on selected study animals to estimate hourly rates of movement and learn about travel patterns during the day. These sessions were conducted twice a season for each individual, once during the day, and once at night. Locations were usually obtained once every 2 hours for each individual, and sometimes were collected more frequently.

All telemetry data were entered into database files (dBase) on an IBM Personal Computer, then transferred to the University of Tennessee IBM 3081 mainframe computer for analysis. Home ranges were calculated using the computer program TELEM (Koeln 1980). In most instances, the convex polygon method (Southwood 1966) was used to estimate home range size. However, some home ranges calculated with this method were artificially inflated because of outlier locations; these home ranges were calculated by the modified minimum area method (Harvey and Barbour 1965) to exclude unused areas of the polygon.

Home range size was estimated annually (when sufficient data were available) and seasonally. Seasons were defined as follows: Fall-September 1 - November 15; Rut-November 16 - December 15; Winter-December 16 - March 15; Spring-March 16 - May 31; Summer- June 1 - August 31.

Program TELEM was also used to analyze data from the 12-hour radiotracking sessions. Variables that were calculated from these data included number of locations, total time tracked, total distance moved, average distance between locations, minimum and maximum movements between locations, activity center, and greatest distance between locations.

Home range and 12-hour movement data were analyzed on the Statistical Analysis System (SAS 1982a). Analysis of variance procedures were used to compare the effects of sex and ageclass, season of the year, and cattle on the size of home range and the hourly rate of movement. The GLM procedure (SAS 1982b) was used to fit models which determined factors that significantly contributed to the observed variation.

Seasonal activity centers were calculated as the mean coordinates of all locations in a given season and analyzed with the GLM procedure. To ensure the detection of a distinct change in seasonal movement patterns, activity centers were considered to be significantly different only if $P<0.01$. For all other statistical tests, the 0.05 probability level was accepted as significant.

Home range plots (seasonal and annual) and study area maps were digitized into computer files using the AE-GIS Geographic Information System (Aeronca Electronics, Inc., Charlotte NC) to analyze general habitat utilization. Home range plots were overlaid onto seasonal habitat maps using the AE-GIS MATRIX procedure and habitat utilization was estimated by the frequency of locations within a habitat category. These variables were subjected to chi square analysis to estimate avoidance or preference of the various habitat types (Neu et al. 1974, Byers et al. 1984).

RESULTS AND DISCUSSION

Movements

Radiocollars were attached to a total of 21 deer, 10 males and 11 females. Radiocollared deer were monitored from 23 days to 480 days (mean=258 days). The dates of monitoring and fate of each study animal are shown in Figures 6 and 7. A total of 2609 locations were obtained, 1988 daily locations and 621 locations from 79, 12-hour monitoring sessions.

The mean annual home range size was 147.2 ha, with males (mean=226.9 ha) ranging over significantly larger ($P=0.0076$) areas than females (mean=107.3 ha; Figures 8 and 9). Adult males had the largest annual home ranges of the 4 sex and ageclass cohorts

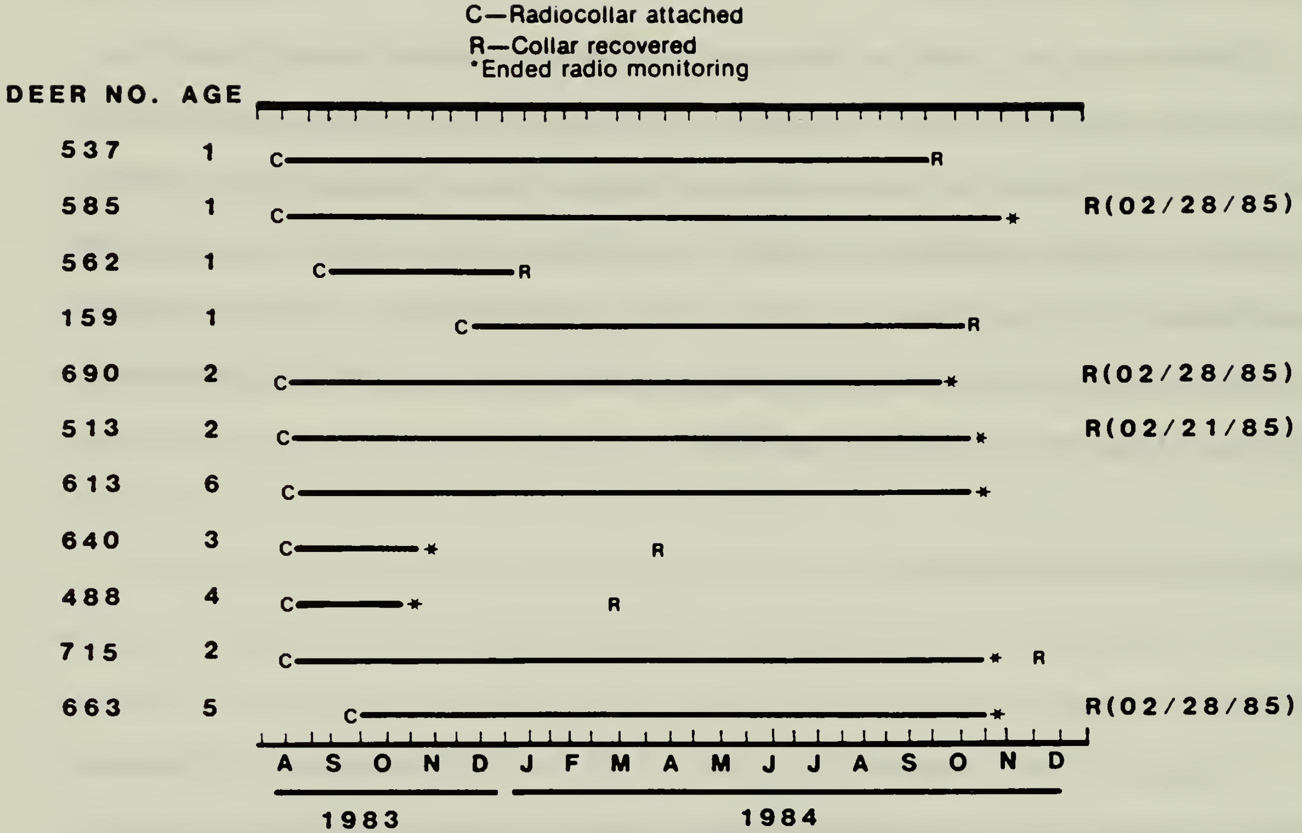

Figure 6. Dates of collaring, duration of radio monitoring, and fate of female white-tailed deer in Cades Cove, GSMNP 1983-84.

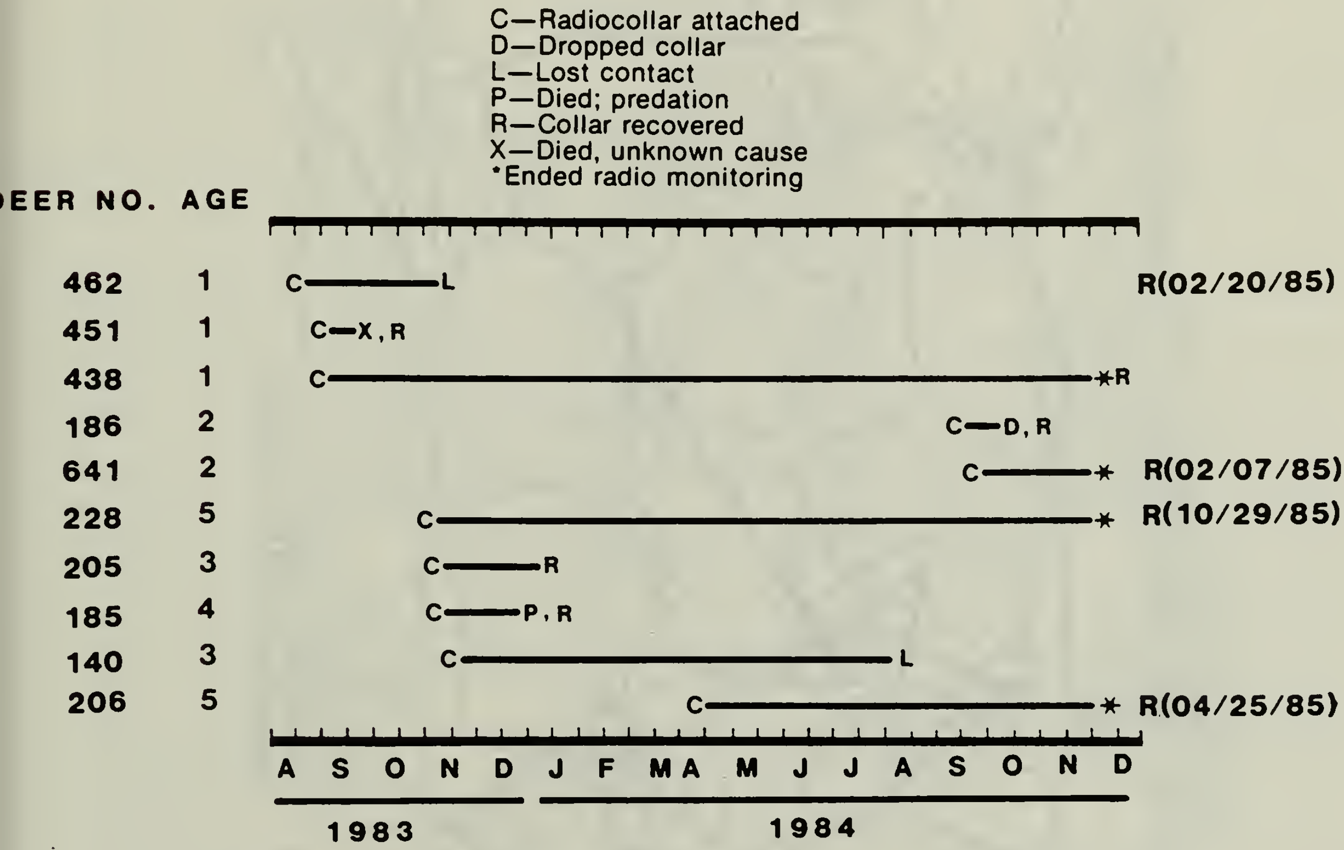

Figure 7. Dates of collaring, duration of radio monitoring, and fate of male white-tailed deer in Cades Cove, GSMNP, 1983-84.

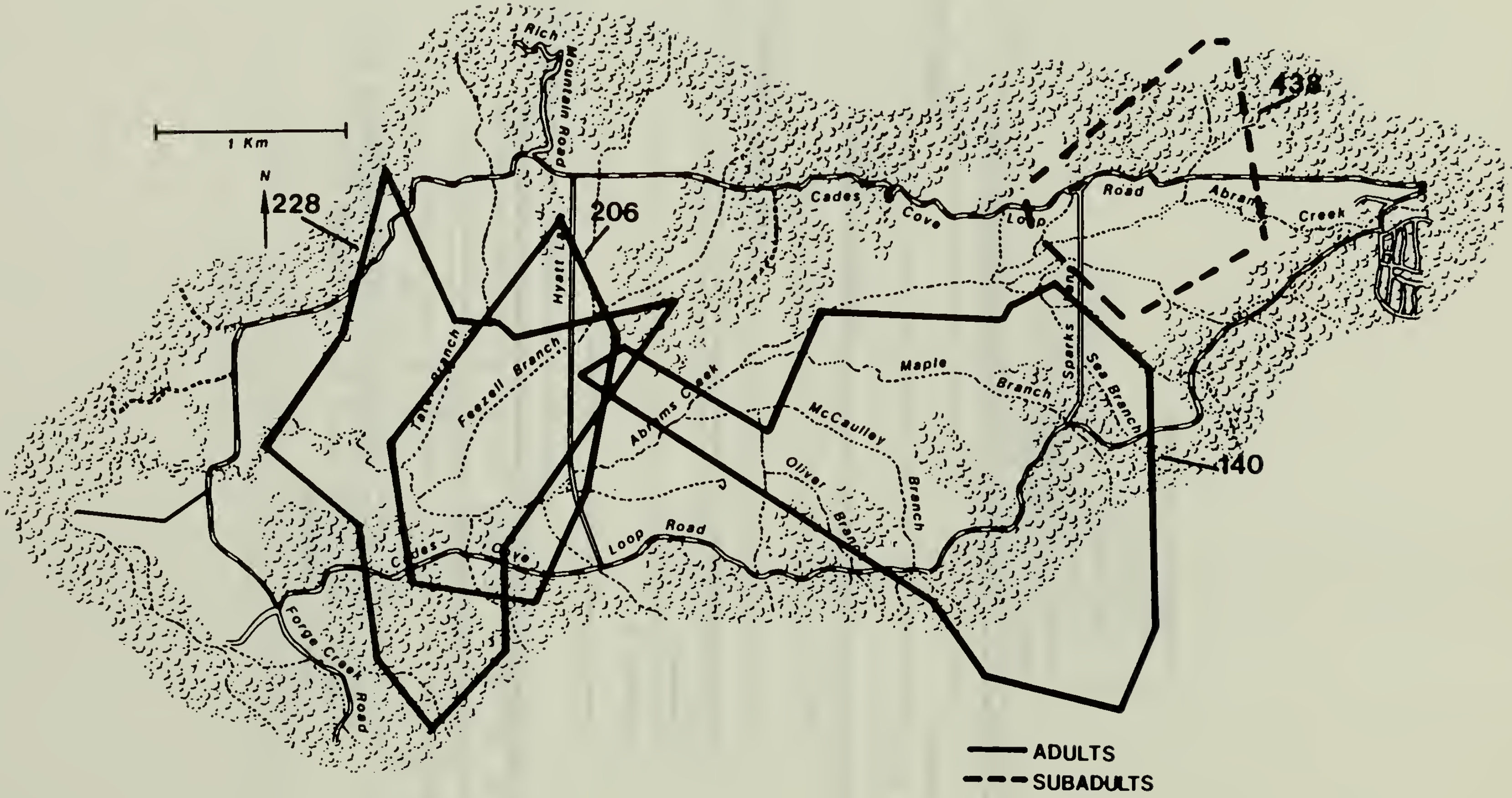

Figure 8. Annual home ranges of male white-tailed deer in Cades Cove, GSMNP, 1983-84.

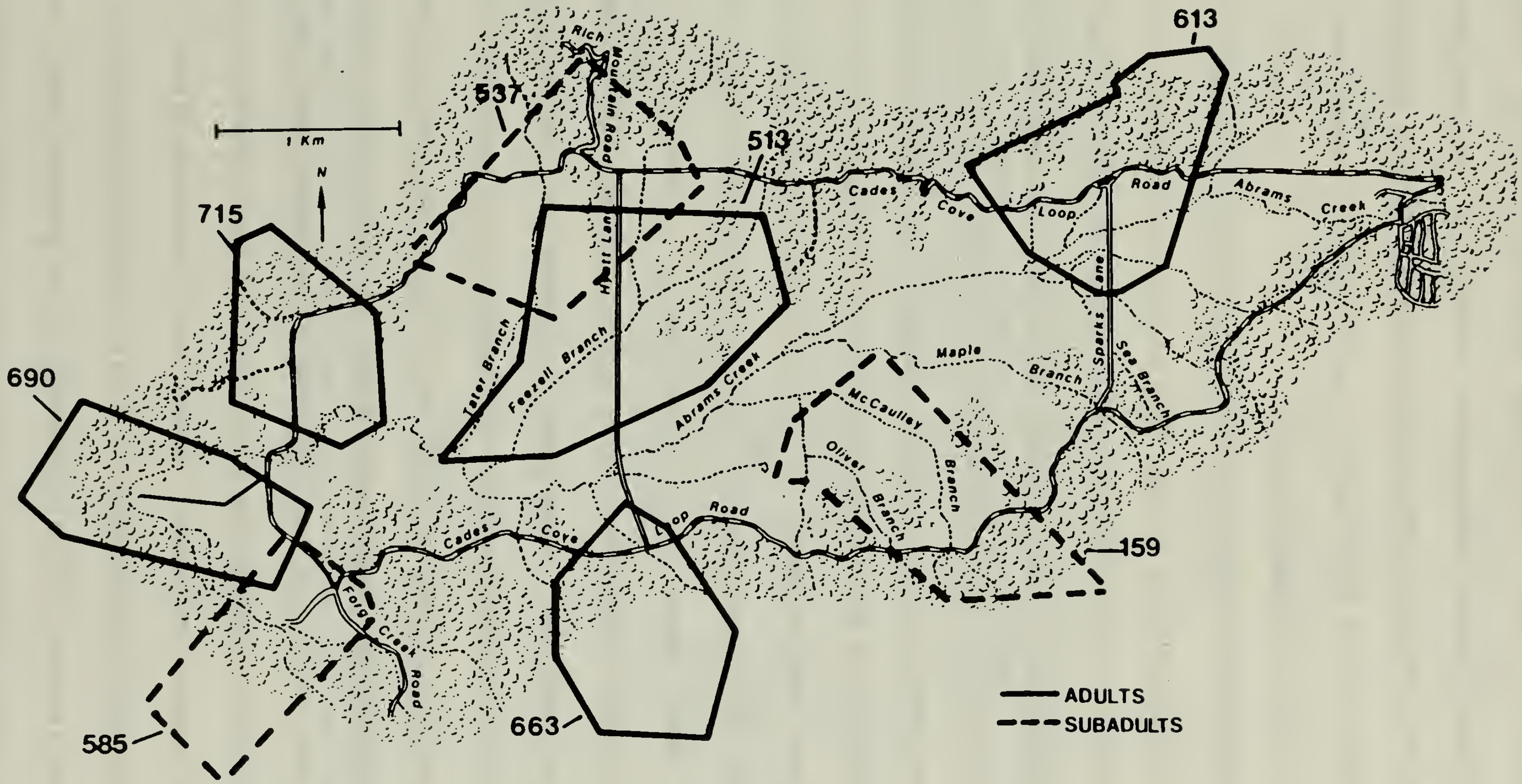

Figure 9. Annual home ranges of female white-tailed deer in Cades Cove, GSMNP, 1983-84.

(Table 13). Analysis of variance showed that sex and the presence of cattle within the home range significantly influenced annual home range size (Table 14). Temporary cattle pastures (pasture utilized by cattle during certain seasons of the year) and permanent cattle pastures are illustrated in Figure 10. Deer that frequently associated with cattle and cattle pastures (mean=182.9 ha) had significantly larger (P=0.0252) annual home ranges than other deer (mean=129.3 ha; Figures 11 and 12).

Average seasonal home ranges are presented in Table 15. Seasonally, home range size was significantly influenced by sex, age class, season, cattle presence, and sex x cattle presence interactions (Table 16). Home ranges during the spring were significantly larger than all other seasons except winter. Somewhat surprisingly, average home ranges during the rut period (mean=39.0 ha) were smaller than other seasons. Of the 4 sex and age class cohorts, adult males (mean=58.8 ha) had the largest home range sizes during the rut (Table 15). Since the peak of the rut was relatively short in duration (about 30 days) when compared to the other seasons (about 90 days), we were able to obtain only about 10 locations per animal, which would partially explain the small home ranges. Nevertheless, in this study there didn't appear to be a great increase in movements during the rut, although most adult males shifted their activity centers. Ivey and Causey (1981) reported that although does increased their activity levels, movements were reduced during the rut.

During 12-hour monitoring sessions, the average rate of movement was 103 m/hr (range=24.5-276.2 m/hr). Overall, no significant difference was detected between males (mean=110.6 m/hr) and females (mean=96.4 m/hr). Mean seasonal movement rates with respect to sex, age class, and diurnal time (day or night) are presented in Table 17.

Analysis of variance indicated that movement rates were significantly influenced by diurnal time, cattle presence and season x diurnal time interactions (Table 18). Sex x age class interactions were nearly significant (P=0.0699), with adult males (mean=112.2 m/hr) and subadult females (mean=115.8 m/hr) moving at the greatest rates. Adult females (mean=83.1 m/hr) moved significantly less than subadult females (P=0.0084) and adult

Table 13. Annual home range size of white-tailed deer in Cades Cove, GSMNP, by sex and age class.

Sex	Ageclass	N	Average Annual Home Range Size (ha)	Range
Male	Adult	3	263.2	165.0-359.0
	Subadult	1	118.0	--------
Female	Adult	5	107.6	74.0-166.5
	Subadult	3	106.8	81.5-126.5

Table 14. Analysis of variance of annual home range size with respect to sex, age class, cattle presence, sex x age class, and sex x cattle presence.

Source of Variation	d.f	M.S.	F	Prob
Total	11			
Sex	1	25358.38	15.55	0.0076
Ageclass	1	4547.39	2.79	0.1460
Cattle[a]	1	14328.02	8.78	0.0252
Sex x Ageclass Interaction	1	4745.30	2.91	0.1389
Sex x Cattle Interaction	1	6691.62	4.10	0.0892
Residual	6	1631.10		

[a] Includes 2 categories: 1) Cow - deer that frequently associated with cattle and cattle pastures; 2) Non-cow - deer that infrequently associated with cattle.

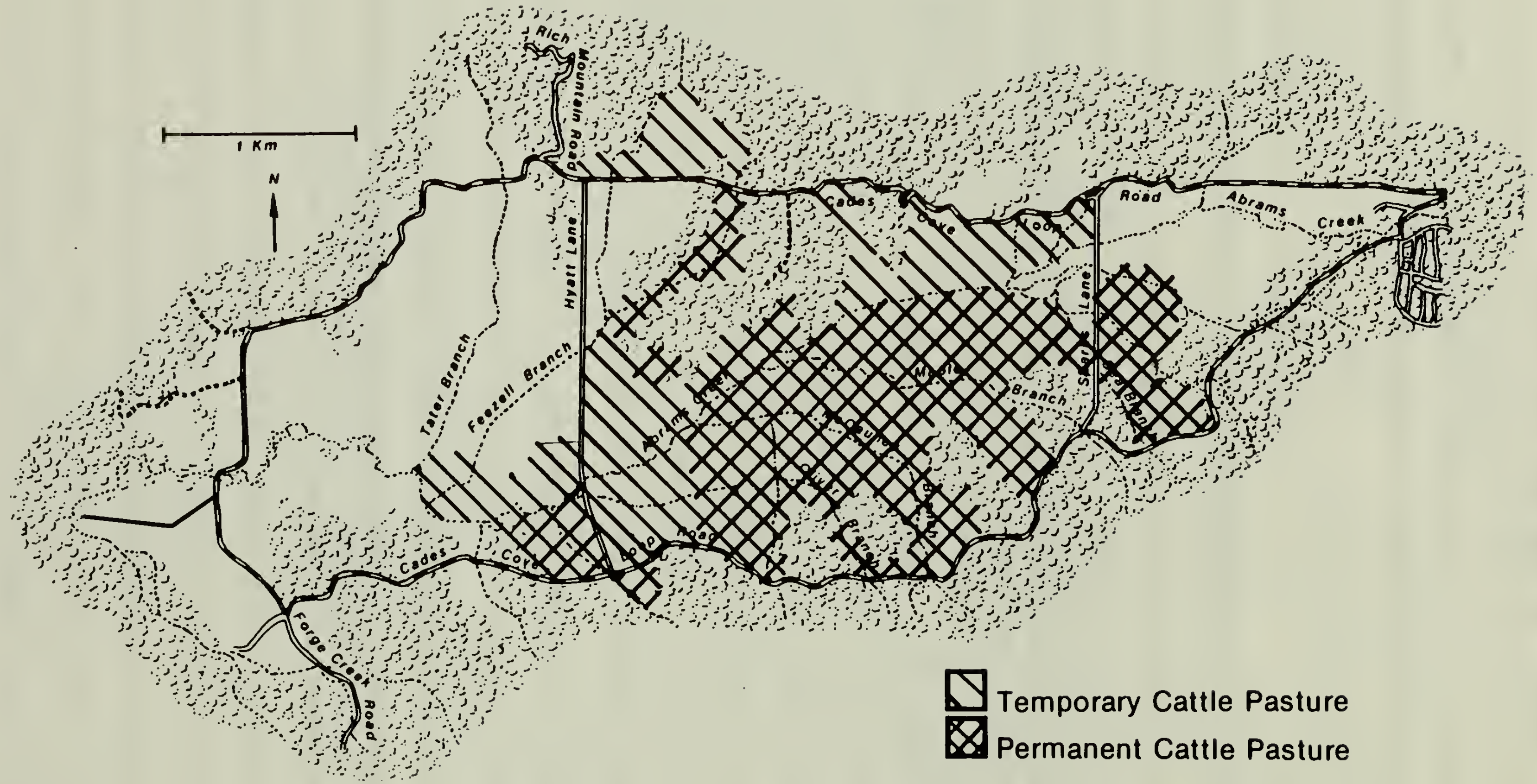

Figure 10. Cattle use of pastures, Cades Cove, GSMNP 1980-1984.

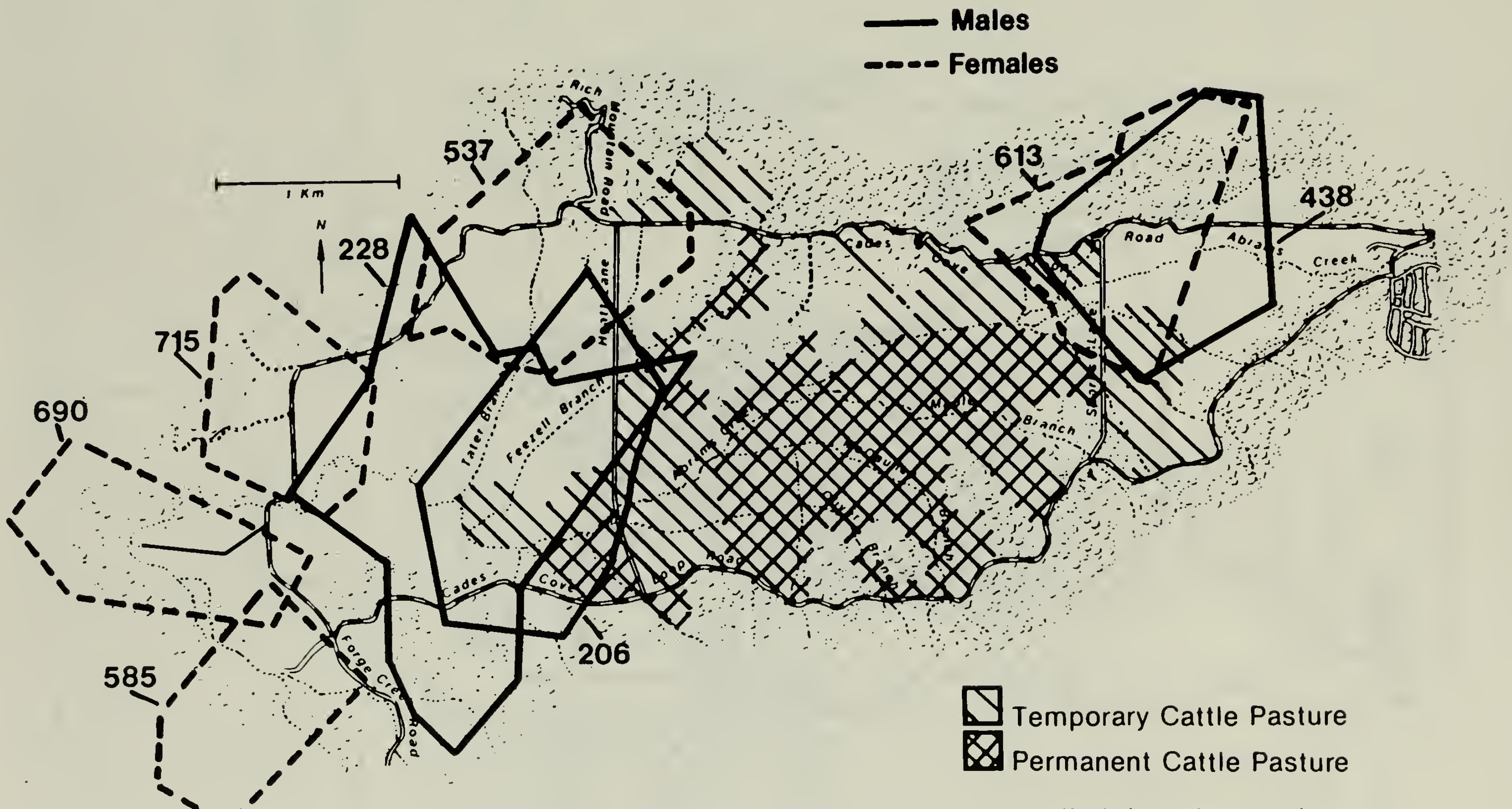

Figure 11. Annual home ranges of white-tailed deer that rarely associated with cattle.

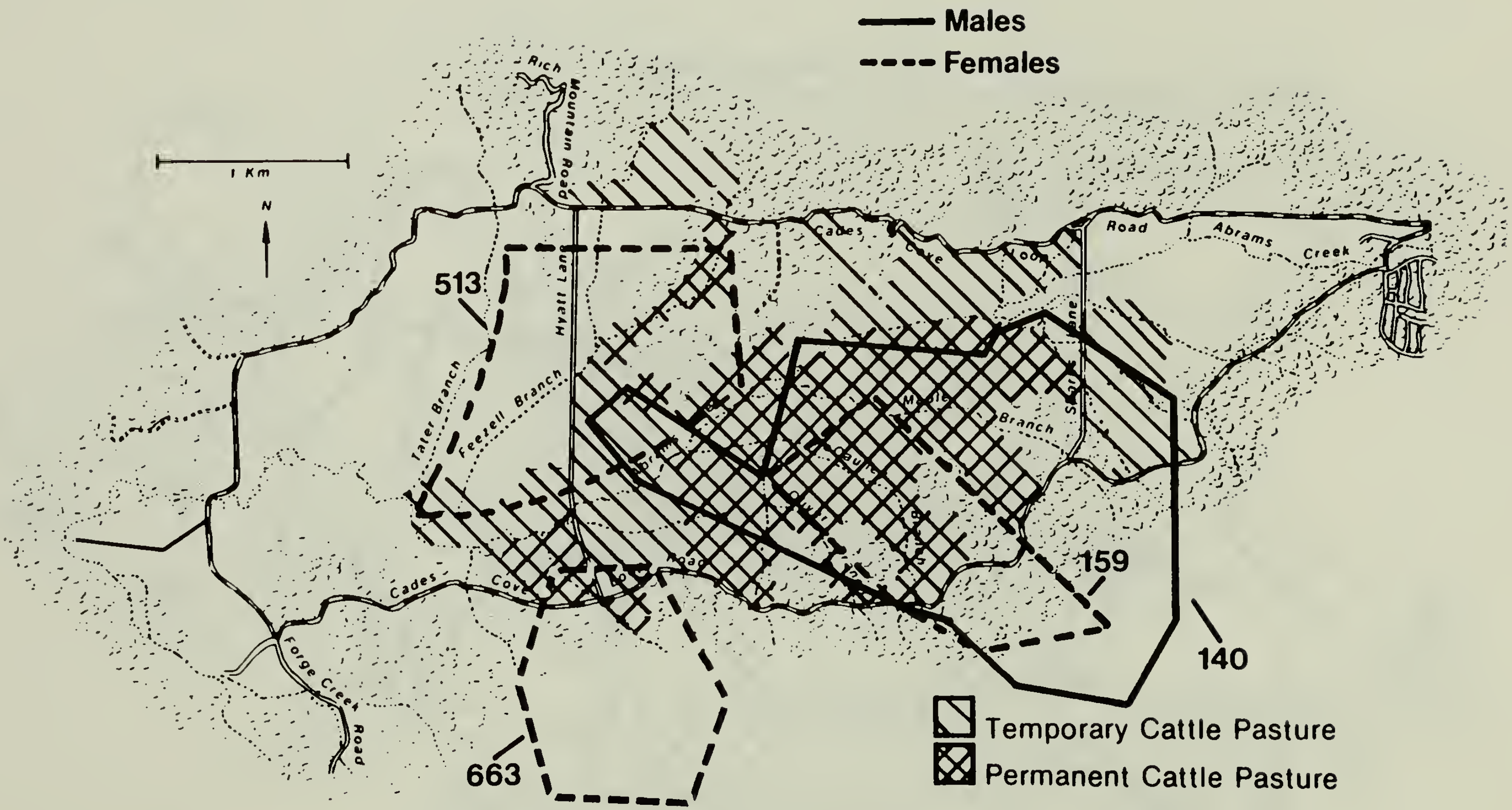

Figure 12. Annual home ranges of white-tailed deer that are frequently associated with cattle.

Table 15. Average seasonal home range size of white-tailed deer in Cades Cove, GSMNP.

	Mean Home Range Size (Ha)				
		Male		Female	
Season	All deer (N)	Adult	Subadult	Adult	Subadult
Winter	57 (11)	101 (2)	39 (1)	53 (5)	41 (3)
Spring	74 (12)	123 (3)	68 (1)	56 (5)	58 (3)
Summer	49 (12)	66 (4)	---	40 (8)	---
Fall	43 (17)	52 (3)	43 (2)	40 (9)	43 (3)
Rut	39 (17)	58 (8)	11 (1)	26 (5)	17 (3)

Table 16. Analysis of variance of home range size with respect to sex, age class, season, cattle presence, sex x age class, and sex x cattle presence.

Source of Variation	df	MS	F	Prob
Total	68			
Sex	1	8456.09	19.83	0.0001
Age class	1	1938.99	4.55	0.0372
Season	4	3606.93	8.46	0.0001
Cattle[a]	1	7653.69	17.94	0.0001
Sex x Age class Interaction	1	1253.71	2.94	0.0917
Sex x Cattle Interaction	1	4072.63	9.55	0.0031
Residual	59	426.53		

[a] Includes 2 categories: 1) Cow - deer that frequently associated with cattle and cattle pastures; 2) Non-cow - deer that infrequently associated with cattle.

Table 17. Average hourly rates of movements of white-tailed deer in Cades Cove, GSMNP.

	Mean Hourly Movements (m/hr)				
		Males		Females	
Season	All deer (N)	Adult	Subadult	Adult	Subadult
		Daytime			
Winter	162.9 (7)	171.7	---	104.4	173.6
Spring	118.0 (7)	114.0	108.3	67.1	140.9
Summer	73.7 (11)	74.8	---	74.5	64.4
Fall	112.2 (7)	111.1	---	97.7	159.1
Rut	131.3 (7)	120.4	173.3	---	144.1
		Nighttime			
Winter	90.2 (10)	93.7	42.8	107.1	90.0
Spring	101.7 (7)	190.8	65.1	50.6	71.7
Summer	101.3 (12)	127.0	---	87.6	94.4
Fall	60.2 (7)	42.8	---	71.5	78.3
Rut	101.8 (4)	101.8	---	---	---

Table 18. Analysis of variance of hourly movements of white-tailed deer with respect to sex, age class, diurnal time, season, and cattle presence.

Source of variation	df	MS	F	Prob
Total	78			
Sex	1	2491.56	1.45	0.2335
Ageclass	1	3369.74	1.96	0.1667
Sex x Age class	1	5852.12	3.40	0.0699
Diurnal Time[a]	1	15600.40	9.06	0.0037
Season	4	1745.42	1.01	0.4072
Cattle	1	20048.51	11.64	0.0011
Season x Diurnal Time Interaction	4	5925.02	3.44	0.0130
Residual	65	2938.47		

[a] Diurnal Types - Daytime, Nighttime.

males (P=0.0041), but not subadult males (mean=112.2 m/hr; P=0.1502). These results were somewhat surprising since it was expected that adult males would move at greater rates than the other sex/age class groups.

Deer moved more during daylight hours than at night (P=0.0037; Table 18) for all seasons except summer when nighttime and daytime movements averaged 101.3 and 73.7 m/hr, respectively. Analysis of the LSMEANS demonstrated that daytime movements were greatest during the winter and rut period (LSMEANS=160.0 m/hr and 135.9 m/hr, respectively), while nighttime movements were greatest during the summer (LSMEANS=122.2 m/hr).

Seasonal changes in activity centers were determined by comparing means of locations for each season with those of the next season. Changes in activity centers were considered to be significant only when P<0.01. Significant shifts in activity centers occurred most frequently from winter to spring (Table 19). For females, significant activity center shifts were more likely to occur from winter to spring (50%) and from spring to summer (50%). Males, on the other hand, shifted most from winter to spring (100%) and from fall to rut (60%). Males shifted activity centers twice as frequently as females (50% vs 24.4%).

The pattern that appeared to be emerging from the analysis of activity centers was that females tended to shift their movements from winter to spring and spring to summer, with very few shifts between other seasons. No significant activity center shifts by females occurred from fall to rut. Males were likely to change activity centers at any time, with winter to spring and fall to rut the most likely times. It was interesting to note that of the 5 "fall to rut" comparisons made for males, the 2 non-significant comparisons were for the same animal during subsequent years, first as a yearling buck, then as a 2-year old. This deer, even as a 2-year old, was relatively immature, and did not regularly associate with buck groups. His movements and observations of him did not indicate that he was an

Table 19. Shifts in seasonal activity centers of white-tailed deer in Cades Cove, GSMNP.

	Fall to Rut	Rut to Winter	Winter to Spring	Spring to Summer	Summer to Fall	Total
Males						
No. comparisons	5	5	3	4	3	20
Significant shifts[a]	3	2	3	1	1	10
Females						
No. comparisons	8	9	8	8	8	41
Significant shifts[a]	0	1	4	4	1	10
Males and Females						
No. comparisons	13	14	11	12	11	61
Significant shifts[a]	3	3	7	5	2	20

[a]Shift is significant when $P<0.01$.

active participant in the rut, although he was observed sparring with other small bucks during the fall of his second year.

The major activity center shifts observed from winter to spring were probably related to a change in feeding patterns. Deer were more likely to be located in the open fields during early spring, presumably because of the emerging vegetation becoming available at this time of year.

The home range size and seasonal movement patterns observed in this study are relatively consistent with those observed in other southeastern areas. It is difficult to compare home range size estimates between different areas, primarily because different methods are used by researchers to calculate home range, such as the minimum convex polygon (Southwood 1966) or non-circular home range (Jennrich and Turner 1969). However, given these limitations, our data indicate that Cades Cove deer are relatively sedentary in their movements, as has been described for white-tailed deer throughout the southeast (Marchinton and Hirth 1984). Other researchers in the south utilizing radiotelemetry have reported average home range sizes from 62 ha (Inglis et al. 1979) to 127 ha (Kammermeyer and Marchinton 1976).

Movement patterns of white-tailed deer are influenced by several factors, including season of the year (Progulske and Baskett 1958, Michael 1965, Downing et al. 1969, Moore and Marchinton 1974), food sources (Byford 1969, Inglis et al. 1979), and hunting (Marshall and Whittington 1968, Kammermeyer and Marchinton 1975). Seasonal home range shifts by deer in the southeast are generally minor (Marchinton and Hirth 1984). However, major shifts have usually been related to the rut (Downing et al. 1969, Moore and Marchinton 1974, Downing and McGinnes 1975, Kammermeyer and Marchinton 1976), and may result in the establishment of a new home range by dispersing bucks (Kammermeyer and Marchinton 1976). Most dispersals from the Crab Orchard National Wildlife Refuge in Illinois were made by yearling bucks (Hawkins et al. 1971).

In the present study, mature bucks displayed significant changes in centers of activity during the rut (Figure 13). No dispersals of radiocollared bucks were documented, but unfortunately, the sample size of young bucks was small. One yearling buck (#462) was observed sparring with larger bucks on 1 and 14 November 1983; radio contact with this deer was lost after 14 November 1983. The collar was aerially located on 11 February 1985, and was retrieved on 20 February 1985. It had been cut off the animal and was located about 11 km from Cades Cove, approximately 1/2 km from the Park boundary next to the Happy Valley community. It is impossible to determine whether this deer dispersed and was shot illegally near the Park boundary (there was no legal deer season in this area), or was poached in Cades Cove and the collar deposited in the woods outside the Park (the collar was located near a well used trail); both of those situations are possibilities in this instance.

Data on the locations of recaptured deer were analyzed to determine dispersal patterns of deer in Cades Cove. The mean distance between captures was 621.7 m (range 0.0-3400.0 m). Males averaged 811.8 m between captures while females averaged 510.3 m; these means were not significantly different ($P=0.1840$). Males which were first captured as 1 or 2 year olds generally had greater recapture distances (mean = 1077.8 m) than other cohorts (Table 20). Two of 9 young males had recapture distances greater than 2000 m, which may have indicated dispersal tendencies in these deer.

White-tailed deer have been observed to make minor and major activity center shifts in response to changing food supplies (Byford 1969, Downing et al. 1969). Similar movement patterns were observed in Cades Cove in our study. The greatest frequency of significant activity center shifts was observed from winter to spring, apparently in response to the availability of emerging vegetation in the open fields. This observation was supported by the high densities of deer observed utilizing fields during the spring, as compared to other seasons (Kiningham 1980, this study).

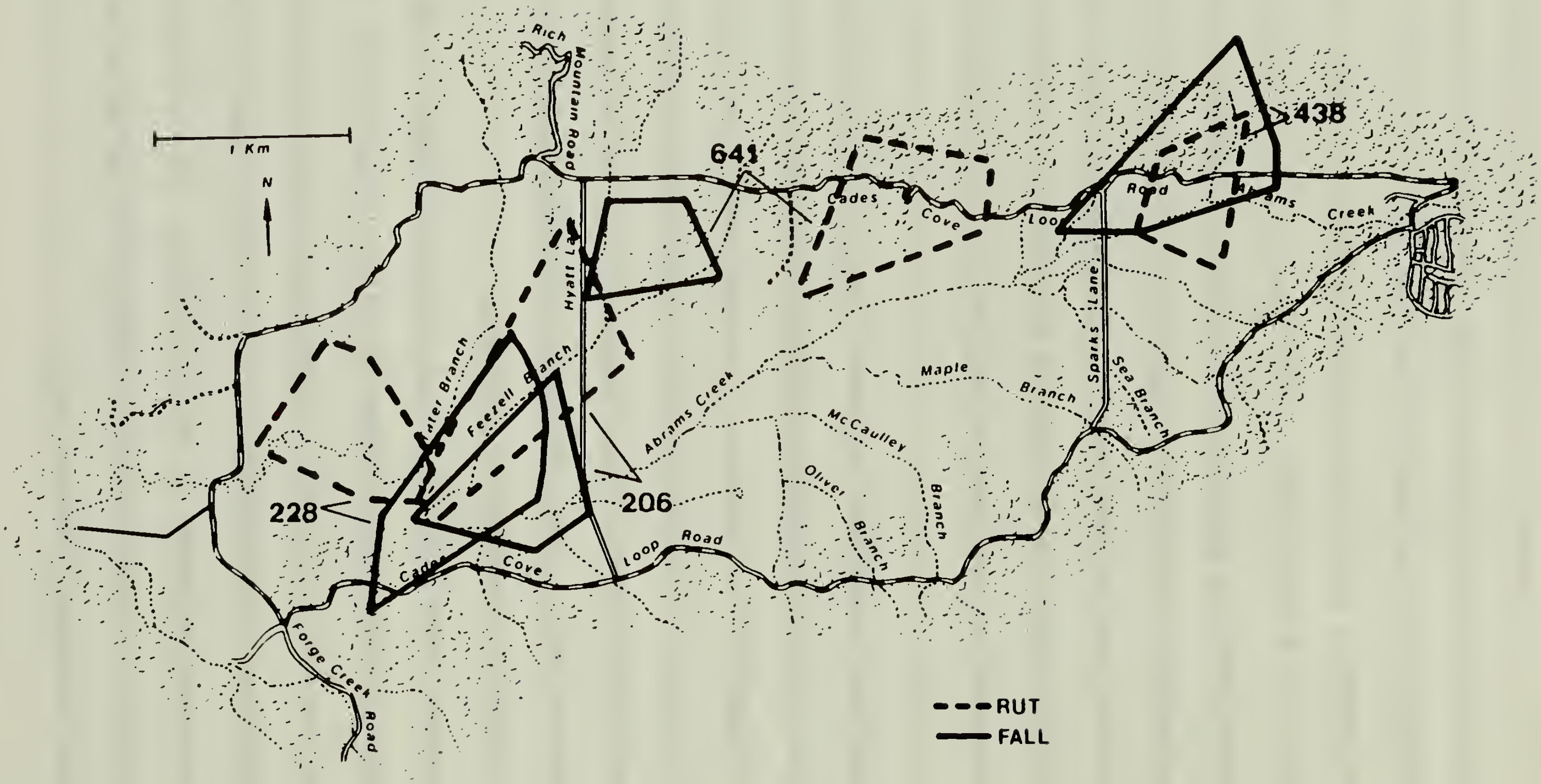

Figure 13. Home ranges of male white-tailed deer in Cades Cove during fall and rut, 1984.

Table 20. Distance between captures of white-tailed deer in Cades Cove, GSMNP, 1980-84.

	Distance between captures (m)				
Group[a]	N	Mean	S.D.	Range	%> 2000 m
Young males	9	1077.8	1095.2	100-3400	22.2
Adult males	6	450.0	327.1	200-1000	0
Young females	20	525.0	332.3	0-1300	0
Adult females	7	514.3	273.4	200-900	0

[a] Young males and young females were first captured as 1- or 2-year olds. Adult males and females were first captured as 3+ year olds.

In the mountains of North Carolina, major altitudinal shifts in home range have been made by deer in response to changes in available food supplies during the spring "green-up" (Downing et al. 1969). These types of movements were not observed in Cades Cove. Winter to spring home range shifts were generally from wooded areas to the open fields. Most of the significant spring to summer home range shifts were made by females, and they were very minor in distance (200-400 m). The selection of areas for fawning sites may have accounted for some of these observed shifts.

Seasonal home range sizes of deer in Cades Cove were influenced by sex and age class, season of the year, and the presence of cattle within the home range. In our study, adult males had larger annual and seasonal home range sizes than other sex/age class groups. Greater movements by male deer have previously been observed by several investigators (Progulske and Baskett 1958, Thomas et al. 1964, Downing et al. 1969, Hawkins et al. 1971, Kammermeyer and Marchinton 1976, Inglis et al. 1979, and others), and is apparently a behavioral characteristic universally exhibited by white-tailed deer. Greater movements by male deer may also have some significance in the transmission and spread of some infectious diseases, such as leptospirosis.

Average seasonal home ranges in Cades Cove were largest during winter and spring. The larger ranges may have been due to deer searching farther for food during these seasons. Byford (1969) observed that deer expanded their movements when food sources were dispersed. When the food supply was localized, deer restricted their movements to those areas (Byford 1969). Some researchers have observed that deer decrease their movements during winter (Dahlberg and Guettinger 1956, Hoskinson and Mech 1976), but most of these observations were made in northern areas, where severe winter weather has a greater impact on deer than in our study area. In Texas, most bucks had larger ranges during winter, whereas seasonal ranges of does were variable with some moving further during winter (Michael 1965). In Virginia, increased movements by does were observed in the summer (Downing et al. 1969).

Our observations demonstrated that deer which associated frequently with cattle and cattle pastures had larger annual and seasonal home ranges, and moved at greater rates than deer that rarely contacted cattle pastures. Other investigators have reported on the influence of cattle on white-tailed deer (Trainer and Hanson 1962, Ellisor 1969, Kramer 1973, Hood and Inglis 1974, Suring and Vohs 1979). In Texas, deer have been observed to change habitat utilization patterns in response to cattle presence (Ellisor 1969, Hood and Inglis 1974). Trainer and Hanson (1962) reported that deer and cattle in Wisconsin were observed associating in pastures, and at watering holes or salt licks.

In Cades Cove, previous studies as well as the current one have found that fewer deer were observed in cattle pastures than in other habitat types (Burst and Pelton 1978, Kiningham 1980). Kiningham (1980) speculated that grazing pressure by cattle may have been sufficient to cause deer to use other areas for feeding. This could explain our observations of large range sizes and greater movement rates of deer that associate with cattle. However, density may also have an effect on deer movements, with movements and home range size decreasing as density increases (Marchinton and Hirth 1984). Since low deer densities were observed in cattle pastures (mean=0.17 deer/ha), it might be expected that deer would be less restricted by social pressures of ranging further than deer in more dense areas.

It is impossible at this time to determine whether cattle presence or deer density has a greater influence on movements of deer in Cades Cove. No studies have been conducted in Cades Cove on the competition for food plant species between cattle and deer, although it has been suggested that livestock have a greater detrimental impact on browse in wooded areas than deer (Bratton 1979a). However, in Louisiana little diet overlap between cattle and captive deer was observed, indicating little competition between the 2 species in that area (Thill and Martin 1979).

Avoidance of cattle by deer may be a behavioral response. Deer have been observed to avoid association with cattle or to be displaced by the movement of cattle into an area (Ellisor 1969, Kramer 1973, Hood and Inglis 1974, Suring and Vohs 1979). Movement data in the present study suggested that when cattle were moved into temporary winter pastures, radiocollared deer using these areas changed movement patterns and avoided these areas. Radiocollared deer reacted in the same manner in response to horses being transferred to temporary pastures. Deer whose home ranges contained significant amounts of cattle pasture also tended to avoid direct contact with cattle, but were less affected by cattle presence, possibly because of their familiarity with cattle.

Habitat Utilization

Seasonal habitat categories and their relative proportions are shown in Table 21; the various habitats are depicted in Figures 14 and 15. The total area available to deer in Cades Cove was approximated by overlaying all annual home ranges on the habitat grid and connecting their outside points (Figure 4; page 26). It should be noted that this represents a "best guess" of the total area that was available to deer.

All chi square goodness of fit tests were significant, indicating that deer did not utilize habitats in proportion to their availability. Bonferroni confidence limits were calculated and compared to the available proportions to determine preference or avoidance of the various habitats by deer (Byers et al. 1984).

The most consistent trends observed were the utilization of hay fields more than expected and the use of wooded areas less than expected (Table 22). This occurred during every season except winter, when both habitats were used in approximate proportion to their availability. In winter, deer were likely to be located in wooded areas during periods of snow cover and on cold nights. Apparently, during all seasons except winter, deer were attracted to hay fields, presumably because of the available grasses and other herbaceous vegetation for food. Wooded areas were not used in proportion to their availability, possibly because of reduced available browse (Bratton 1979a). In winter, deer utilized hay fields, especially during the afternoon hours, although the available food resources were

Table 21. General habitat categories and the relative seasonal proportions used to evaluate habitat utilization by deer in Cades Cove, GSMNP.

Habitat	Area [ha (%)][a] 1	2
Hay Field	457.40 (18.6)	331.04 (13.5)
Wooded Area	1573.44 (64.1)	1573.44 (64.1)
Horse Pasture	62.84 (2.6)	----
Cattle Pasture	307.56 (12.5)	289.00 (11.8)
Hay/Horse[b]	----	105.60 (4.3)
Hay/Cattle[b]	----	103.20 (4.2)
Other[c]	53.32 (2.1)	52.24 (2.1)

[a] 1 = areas used in analysis for summer, fall, rut, and spring seasons; 2 = areas used in analysis for winter season.

[b] Hay/Horse and Hay/Cattle habitats were areas which were temporarily occupied by livestock.

[c] Includes Historical/Human Use areas and Old Fields.

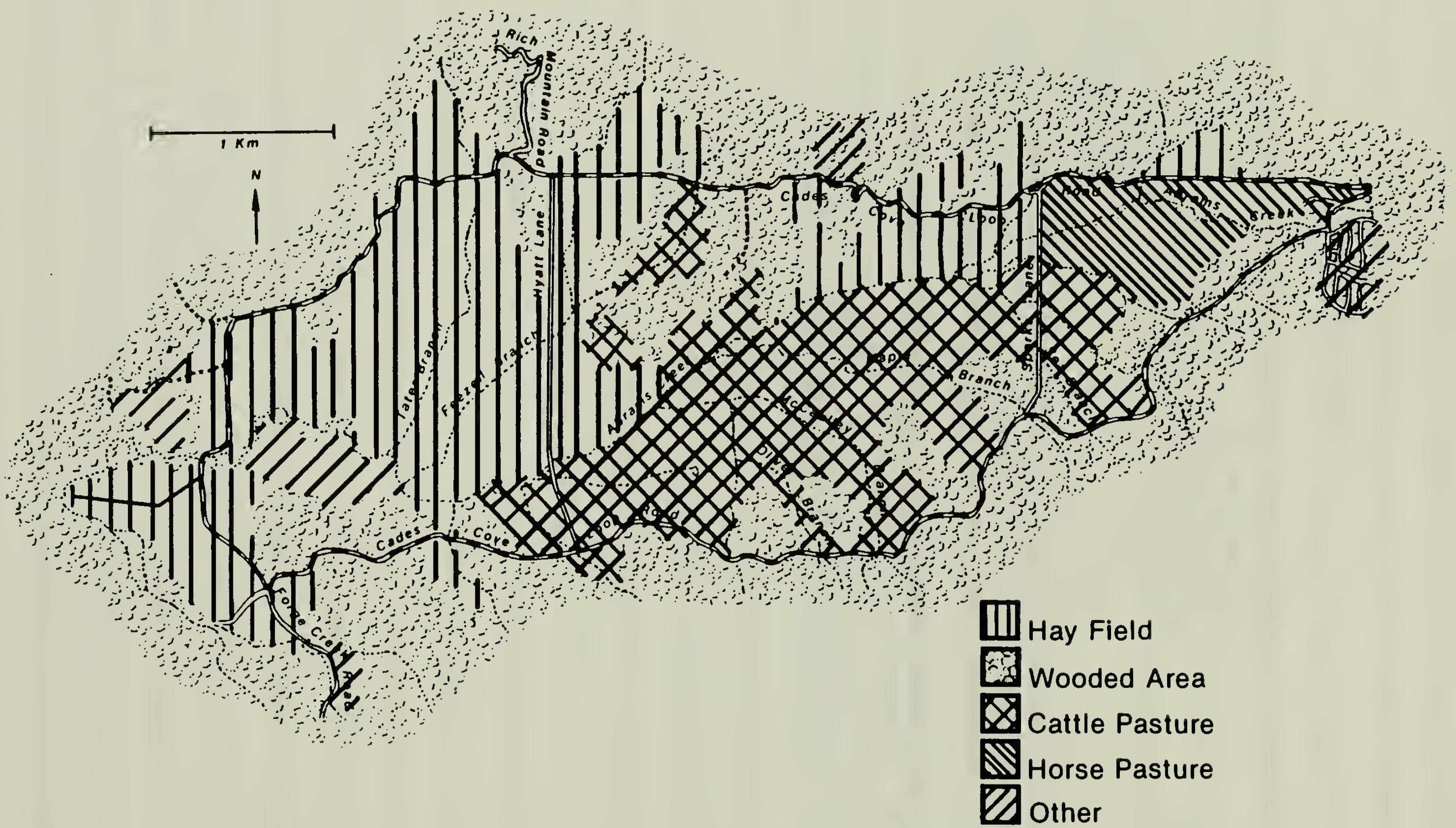

Figure 14. Habitats of Cades Cove during the summer, fall rut and spring seasons.

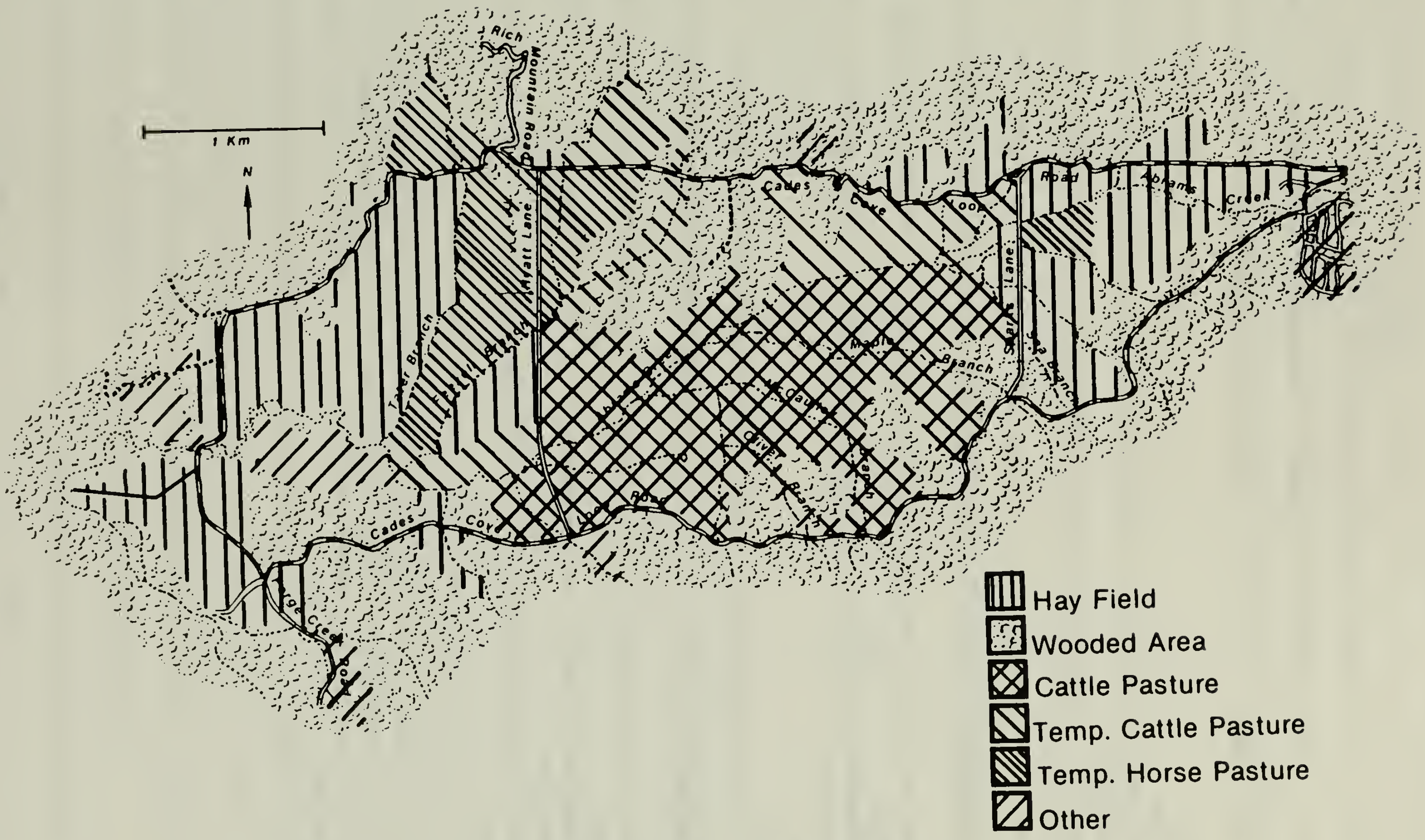

Figure 15. Habitats of Cades Cove during the winter season.

Table 22. Seasonal habitat utilization patterns of white-tailed deer in Cades Cove, GSMNP.[a]

Habitat	Season				
	Fall	Rut	Winter	Spring	Summer
<u>All Deer</u>					
Hay Field	+	+	0	+	+
Wooded Area	-	-	0	-	-
Horse Pasture	+	0		0	0
Cattle Pasture	-	0	-	0	0
Hay/Horse			+		
Hay/Cattle			0		
Other	0	0	0	0	-
<u>Females</u>					
Hay Field	0	+	0	+	+
Wooded Area	0	-	0	-	0
Horse Pasture	0	0		0	0
Cattle Pasture	0	-	-	0	-
Hay/Horse			+		
Hay/Cattle			0		
Other	0		-	0	-
<u>Males</u>					
Hay Field	+	+	0	+	+
Wooded Area	-	-	0	-	-
Horse pasture	0	0		0	0
Cattle Pasture	-	0	-	0	0
Hay/Horse			0		
Hay/Cattle			0		
Other	0	0	0	0	

[a] + = habitat used more than expected; 0 = habitat used in proportion to its availability; - = habitat used less than expected.

certainly more reduced than other seasons. Wooded areas are probably important as cover during winter snows and on cold nights.

Other than the trends observed with hay fields and wooded areas, there were no other consistent preferences or avoidances demonstrated by the data. Few concrete conclusions can be formulated from this generalized analysis of the data. However, some observations are worthy of mention.

During winter, a special situation arose in which cattle and horses were moved into temporary pastures (Hay/Cattle and Hay/Horse habitat categories). The seasonal data indicated a preference for the Hay/Horse areas, but no preference or avoidance for temporary cattle pastures (Table 22). However, more detailed investigation of the data indicated that deer movements temporarily changed in response to the movements of cattle and horses into these pastures. When livestock were moved out, deer would resume utilization of the area.

Deer which had cattle pastures within their home ranges exhibited neither preference nor avoidance for cattle pastures in every season except summer when cattle pastures were used less than expected. Generally, it was observed that deer which had home ranges bordering expansive areas of cattle pastures utilized those pastures. One exception was deer #663, a female; nearly 90% of her annual home range was in wooded areas (Figure 12). Other deer, which had only small areas of cattle pastures within their home range, were located most often in areas other than cattle pastures, especially hay fields.

Our spotlight count and telemetry data indicated that, as a whole, deer in Cades Cove utilized cattle pastures to a lesser degree than other habitats. However, telemetry data demonstrated that these pastures were not totally avoided by deer. Indeed, they were utilized frequently by deer whose home ranges contained cattle pastures.

Competition between cattle and deer is generally not considered serious as long as the range is not overgrazed (Dasmann 1981, Crawford 1984). Some investigators have found that rotation grazing by livestock can be beneficial to deer range (Reardon et al. 1978, Crawford 1984). Continuous grazing by livestock is generally considered detrimental to deer, and cattle grazing in woodlands is discouraged by wildlife managers because of competition for forage (Crawford 1984). Even though deer and cattle may use the same areas they have been observed to avoid close contact (Kramer 1973, Suring and Vohs 1979, Kiningham 1980). The same was observed in the present study; deer were often displaced by cattle moving into an area, as has been observed by other researchers (Ellisor 1969, Kramer 1973, Hood and Inglis 1974, Suring and Vohs 1979).

INFECTIOUS DISEASES

Evidence of several infectious diseases was found in the deer herd of Cades Cove. In some cases, infection was manifested by clinical disease, whereas with other agents only serologic evidence of the presence of an agent was found.

METHODS AND MATERIALS

Beginning in 1980, white-tailed deer in Cades Cove were immobilized as part of a graduate research project.

In the early phase of the project, a variety of tranquilizing/immobilizing agents were tried in order to determine the best immobilization technique for sample collection. Succinylcholine chloride (Anectine^{R}) was determined to be the drug of choice. The Pneu-dart rifle system was used to deliver this drug.

At first, darting was conducted by a small group of individuals. Few deer were immobilized during this early phase. Late in 1980, as part of a deer restoration project, several teams of darters were provided by the Tennessee Wildlife Resources Agency. This allowed large numbers of deer to be captured in a shorter period of time. These teams worked during December, January and February. Major capture efforts as part of the restoration project continued periodically through 1984 with the exception of 1983 when no effort was made to capture and relocate deer.

In 1983 and 1984, two teams accounted for many of the deer captures. This arrangement allowed deer to be captured on a weekly basis although not in high numbers. Figure 16 illustrates the approximate darting locations of the deer.

Except when darted during the restoration project, deer were released back to the Cove after blood sample collection. Veterinary care was available during the major restoration capture efforts, and when only two teams were working, personnel were trained in resuscitation techniques in the event of an overdose of succinylcholine chloride (SCC).

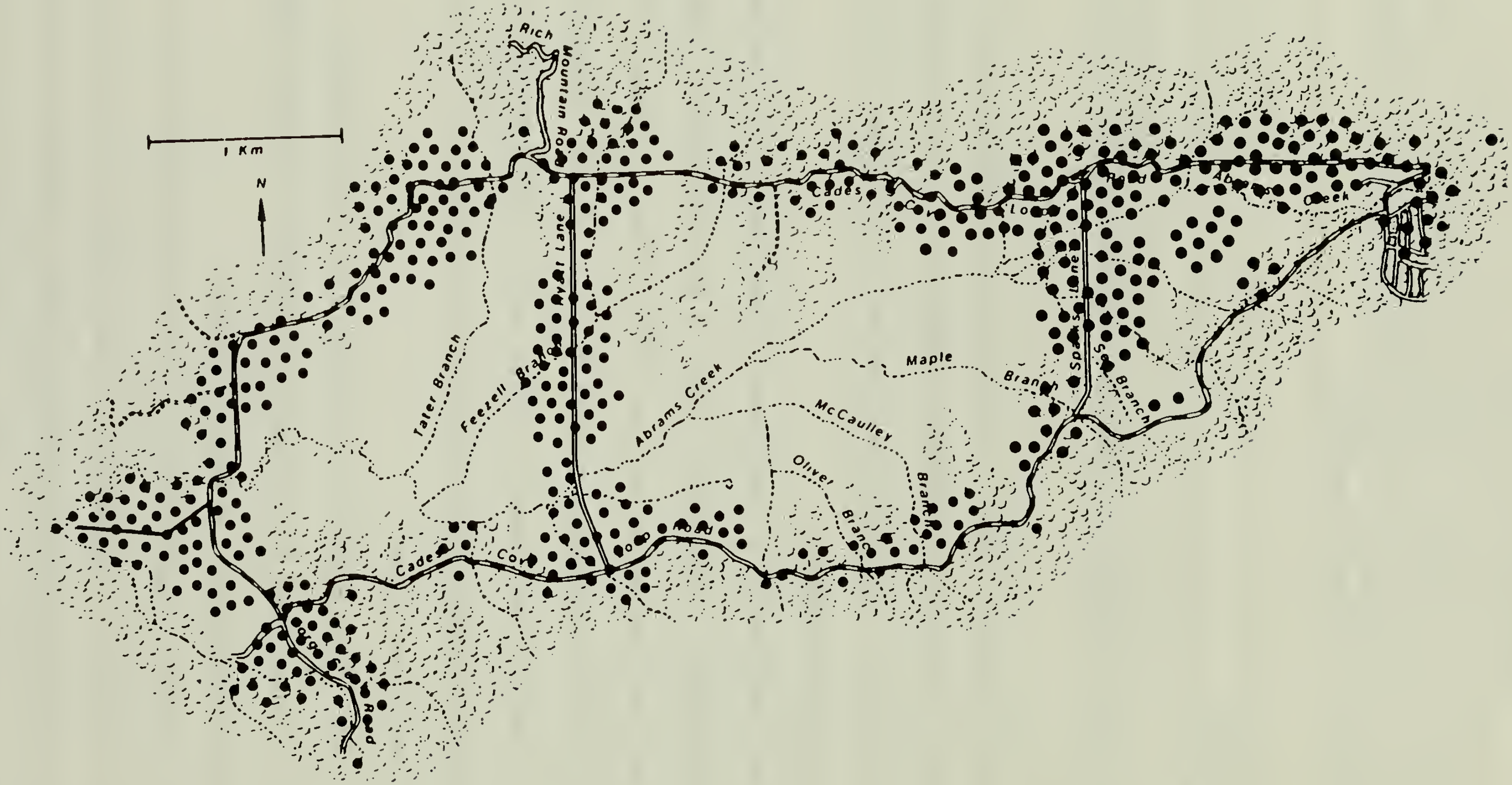

Figure 16. Approximate darting locations of white-tailed deer, Cades Cove, GSMNP, 1980-1984.

Oxygen and/or a device which allowed mechanical respiration (an Ambu bag) was available for resuscitation purposes. Despite this precaution, some deer were lost. Yearling bucks seemed to be at highest risk. It is unknown whether this was due to drug overdoses or an inherent factor in this age class.

Almost all darting was done at night using spotlights after the Cove had been closed to visitors. Because of the limitations of the capture equipment, deer had to be within approximately 40 meters of the road. Vehicles were not driven into the fields for darting. Deer also had to be in open fields instead of woodlands so they could be visualized after darting.

When a deer was observed in an appropriate setting, weight was estimated and the range adjusted on the rifle. In general, 6 to 7 mg of SCC was used for does and 7 to 9 mg for bucks. Immature deer were not intentionally darted except as part of the telemetry study when subadults were included.

If a dart was properly placed, usually in the muscles of the hip, and was of the proper dose, the animal could be expected to be recumbent within 5 to 7 minutes. Recumbancy within two minutes of darting was a possible indication of overdose. If deer remained standing and showed no signs of ataxia for up to 15 minutes after darting, it was considered too low a dose.

Once immobilized, the deer was checked for obvious lesions of disease and ventilation was assisted if necessary. Blood samples were collected from the jugular vein using the Vacutainer^R system. Hair and muscle (biopsy) samples were collected from some animals for a collateral research project. Age estimates were based on tooth wear and replacement (Severinghaus 1949). Because many people were involved in the collection of samples over the 5 years of the project, and experience in aging varied considerably, age was collapsed into two age classes (adult = $\geq$ 1.5 years, subadults = $<$ 1.5 years) for the purpose of analysis.

Most animals were ready to stand when sample collection was completed. In many instances, physical restraint had to be applied for the last few minutes of sample collection. If an animal died, it was usually brought to the UT College of Veterinary Medicine for necropsy. This was in order to assess potential underlying disease conditions that might have contributed to the cause of death.

Blood samples were refrigerated after being allowed to clot and the sera decanted 12 to 24 hours after collection. Sera were kept in an ultracold freezer (-70^{0} F) until analyzed. EDTA blood was drawn from several deer for virus isolation when hemorrhagic disease was suspected. Red blood cells were washed free of serum and stored in an ultracold freezer in 10% buffered saline.

Five hundred eighteen deer were sampled from 1980 thru early 1985 (Table 23). Some of these deer were darted twice allowing paired blood samples and a few deer were darted three times with blood being collected each time. Consequently, 590 blood samples were drawn from 518 deer during the course of the study (Tables 24 and 25).

Data on population dynamics and movement patterns of the deer herd reported earlier were designed to assess the effects of movement and density on some of the infectious diseases of interest. Estimation of the size of the herd was based on the mark/recapture technique. By this method, the number of adults in the herd was approximately 571 to 576. When fawns were added, herd size was estimated to be 635 deer.

Using these population estimates, the percent of the herd sampled was calculated by year. Fifty deer were sampled in 1980, which represents approximately 8% of the estimated deer herd. The approximate percent of the herd sampled was 20% in 1981, 18% in 1982, 18% in 1983, and 29% in 1984. Recaptures within the same year are not included in these figures. The average level of sampling for 1980 thru 1984 was 19%.

Table 23. Number of deer sampled, Cades Cove, GSMNP, 1980-1984 by sex and age class.

	Adult[a]		Subadult[a]			
Sex	Frequency	Percent	Frequency	Percent	Total	Percent
Male	115	24.8	54	11.7	169	36.5
Female	230	49.7	64	13.8	294	63.5
Total	345	74.5	118	25.5	463[b]	100

a. Adult = $\geq$ 1.5 years, subadult = <1.5 years

b. 55 data sheets (10.6%) were missing sex and/or age data. Total number of deer sampled, 1980-1984, was 518. 590 blood samples were collected from these 518 individuals.

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Table 24. Number of white-tailed deer blood samples collected, Cades Cove, GSMNP, 1980-1985, by sex and age class.

	Adult[a]		Subadult[a]			
Sex	Frequency	Percent	Frequency	Percent	Total	Percent
Male	142	26.6	58	10.9	200	37.5
Female	267	50.1	66	12.4	333	62.5
Total	409	76.7	124	23.3	533[b]	100

a. adult = $\geq$ 1.5 years, subadult = < 1.5 years

b. 57 data sheets (9.7%) were missing sex and/or age data. Total number of blood samples collected was 590 from 518 individuals.

****

Table 25. Number of white-tailed deer recaptured after collection of an initial blood sample, Cades Cove, GSMNP, 1980-1985.

Number of Deer recaptured	Frequency	Percent Recapture	Sex Male	Sex Female
once after initial capture (two blood samples collected)	54	10.4	20	34
twice after initial capture (three blood samples collected)	9	1.7	5	4

Cattle are pastured in the Cove by permit and pasture areas incorporate or overlap the home range of many of the deer (Figure 10). The permit holder is allowed to maintain 500 units in the Cove. A unit is defined as one adult or a cow and her calf.

A cattle census was conducted twice during the study period in order to estimate the average population size. For the purpose of the census, all individuals, cows, calves and bulls were counted - not cattle units. Four hundred and ten animals were counted in October, 1983 and 434 in May, 1984. The average was 422 head.

Cows and calves are usually pastured south of Abrams Creek between Hyatt and Sparks Lane (Figure 10). The pastures immediately east of Sparks Lane are also used for cows and calves. Steers are often pastured north of Abrams Creek and utilize the fields north of the entrance to Hyatt Lane in the winter. Steers are marketed at about two years of age. Several bulls are pastured in the field at the southwest end of Hyatt Lane.

The cattle herd receives very little veterinary care due to the remoteness of the site. Routine vaccinations and dewormings are rare. Small groups of cows and young stock may be vaccinated if collected for some other reason. There are minimal equipment and facilities available for handling animals, and animals are handled primarily for castration and marketing. Salt/mineral blocks are made available for the cattle and are used by the deer also.

Blood samples were collected from the cattle herd twice during the study period. Thirty-nine samples were collected from steers sent to a local auction market and 16 samples were collected from young stock (< 2 years) being moved within the Cove. One additional sample was collected from a cow with severe respiratory distress which later died. No necropsy was performed, but based on a physical exam and the blood sample, the cause of death was probably pneumonia possibly initiated by infectious bovine rhinotracheitis virus.

A total of 56 blood samples were collected from the cattle herd during 1983 and 1984. This represented 13% of the herd based on the census average. These samples were not randomly selected, nor were they representative of all areas of the Cove or all age groups. With the exception of the sample from the sick cow, all samples were drawn from apparently healthy animals between 1 and 2 years of age.

Darting-Related Mortality

When the study was first begun as a graduate student project, a variety of immobilization drugs were tried. SCC was the drug of choice because when dosed properly, immobilization and recovery were rapid. The drug is inexpensive, not regulated by the Drug Enforcement Agency, and represented a minimal human health hazard compared to other agents. It was also compatible with the rifle delivery system available to the investigators.

SCC has two major disadvantages. It is unstable and can lose potency unless carefully stored at proper temperature and humidity. Even more important, is its nonreversibility. If overdosed, succinylcholine chloride can cause death due to paralysis of the muscles of respiration. There is no depressant action on the brain (Smith et al. 1986).

Although the effects of succinylcholine chloride cannot be reversed by other pharmacologic agents, it is possible to mechanically breathe for the overdosed animal until the effects of the drug wear off. When the authors took control of this study in 1982, resuscitative equipment was made available whenever deer were being immobilized. Mechanical respiration was successfully used several times during the course of the study.

Even with the precautions above, mortalities were expected. A critical element in proper dose is a realistic estimate of weight prior to darting. Risk of mortality is related to the ability of the darter to estimate weight.

Darters in this study can be divided into three general categories: inexperienced, experienced and very experienced. These categories are based on specific experience with the drug and in the use of darting equipment. All darters had reasonable to extensive marksmanship skill.

The initial graduate student involved in the project had marksmanship experience but was inexperienced in darting prior to beginning this project. During 1980, this individual immobilized 50 deer using several drugs singly and in combination. This was a period when the darter was gaining experience and trying to determine the best immobilization drug or combination of drugs to use.

Fourteen darting related deaths occurred from these 50 immobilizations resulting in a 28% mortality rate. Only field necropsies by the darter were performed so underlying disease conditions which may have caused or contributed to the cause of death were not documented. Data sheets from this period were often incomplete regarding age or sex so an analysis of risk based on age class or sex was not possible. An increased risk of mortality based on age class and/or sex was noted with the other two categories of darters.

The experienced category of darter is represented by wildlife officers who participated in the four intensive darting periods as part of a restoration project. Few of these individuals had extensive darting experience. Those who had darting experience used the technique only sporadically a few times a year. Consequently, expertise varied.

The average mortality rate for this category of darter was 10.7%, significantly less than that of the 1980 period. SCC was the only drug used for immobilization during the restoration project.

The very experienced darter is characterized by a person who developed darting expertise over time by darting on a regular basis. These individuals would often dart on a weekly basis using SCC. This not only allowed the development of skill but also promoted the maintenance of that skill.

Two hundred and forty deer were immobilized by this category of darter. Eighteen of these deer died representing a mortality rate of 7.5%. This represents an approximate 30% reduction in mortality compared to experienced darters. Consistent use of the technique no doubt contributed to this reduction but the immediate availability of resuscitative equipment also contributed.

When dartings were conducted for the restoration project, several darting teams (experienced) were active in the Cove each night. After a deer was darted, it was brought to a central station where samples were collected. Because resuscitative equipment and personnel trained to use the equipment was limited, equipment and trained personnel were assigned to the central station. In some cases, an overdosed deer would die before it could be brought to the central station.

In contrast, there were usually no more than two teams per night when darting was being done by very experienced darters. This allowed resuscitative equipment and trained personnel to be present on each truck. When needed, resuscitative equipment was immediately available. This no doubt contributed to the reduced mortality seen with this category of darters. Both consistent use of the technique and the immediate availability of resuscitative equipment contributed to reduced mortality.

It was the impression of the investigators early in the study that risk of mortality may be related to age class and/or sex factors. Table 26 displays mortality rates based on age class, sex and type of darter. Data were too incomplete to allow analysis of mortality by age class and sex for inexperienced darters.

Another study that discussed mortality related to the use of succinylcholine chloride reported a mortality rate of 14.3% in fawns and 7.1% in adult deer. Wide differences in the dose ranges for successful immobilization was attributed to seasons of the year (Scanlon and Mirachi 1973).

In the current study, the younger animals (<1.5 years) were at greater risk of mortality than older animals and males were at greater risk than females (Table 26).

Mortality rates by age class and sex were consistently lower for very experienced darters compared to experienced darters. In young animals, the mortality rates for very experienced darters were less than half that for experienced darters.

On occasion, young animals were mistaken for adults and subsequently darted with an adult dose. This would explain part of the difference between mortality rates in the

Table 26. Darting related mortality of white-tailed deer by age class, sex, and experience of darter.

	Males		
	<1.5 years of age	≥ 1.5 years of age	
	% Mortality	% Mortality	Total
Experienced Darters	36.4 (4/11)*	7.7 (3/39)	14.0 (7/50)
Very experienced Darters	15.8 (3/19)	5 (5/101)	6.7 (8/120)
Total	23.3 (7/30)	5.7 (8/140)	8.8 (15/170)

	Females		
	<1.5 years of age	≥ 1.5 years of age	
	% Mortality	% Mortality	Total
Experienced Darters	30.8 (4/13)	7.5 (15/199)	9.0 (19/212)
Very experienced Darters	12.5 (2/16)	5 (4/80)	6.3 (6/96)
Total	22 (13/59)	6.4 (27/419)	8.1 (25/308)

* number died/number immobilized.

young and adult animals. However, the investigators believe that a biological difference may also be involved.

All mortality rates discussed are based on deer that were captured after darting. There were deer that were darted but escaped. Some of these may have died, so the true mortality rates are unknown.

In summary, when SCC is to be used to immobilize white-tailed deer, darters with consistent experience with the technique and the availability of resuscitative equipment may reduce mortality due to overdose by up to 30%. Young deer especially males, may be at higher risk of mortality even with the precautions indicated above. Telemetry data and data on mortality not related to darting also indicated males to be more susceptible to mortality factors.

Wildlife Serum Bank

Sera from the herd have been stored in an ultracold freezer since 1980. This serum bank will serve as a resource for future investigations and research.

HEMORRHAGIC DISEASE

Hemorrhagic disease is a generally accepted term used to describe bluetongue (BT) and/or epizootic hemorrhagic disease (EHD) virus infection in white-tailed deer (Nettles 1982). These virus infections are clinically indistinguishable from each other and can be differentiated only by serologic analysis and/or virus isolation. Bluetongue and EHD are defined as infectious, non-contagious viral diseases of ruminants transmitted by insects. Clinical manifestations of infection are characterized by inflammation and congestion of the mucous membranes leading to cyanosis, edema, hemorrhages and ulceration (Luedke et al. 1977, Metcalf and Luedke 1979).

Metcalf and Luedke (1979) revised an extensive review of bluetongue and related diseases, particularly EHD, that included the following history. In the late 1800's BT was described as a disease of imported European breeds of sheep in South Africa although it had apparently been recognized since the first importations of sheep in the 1700's. In the United States, a clinical entity called "mycotic stomatitis" in cattle was described between 1889 and 1904 which was identical to the description of BT in cattle in South Africa and elsewhere. BT virus was isolated from California sheep in 1952 and was first recognized in U.S. cattle in 1959.

EHD virus was first recovered from a white-tailed deer in a major die-off in New Jersey in 1955. The virus has since been recovered from cattle with clinical disease identical to BT.

Hemorrhagic disease occurred in white-tailed deer of seven Southeastern states during the late summer and early fall of 1971. The disease first appeared in South Carolina and then erupted almost simultaneously in Florida, Georgia, Kentucky, North Carolina, Tennessee and Virginia (Prestwood et al. 1974). Both BT and EHD viruses were isolated from these 1971 die-offs (Thomas et al. 1974). During this period, a die-off occurred in the Cades Cove area resulting in an 84% decrease in the number of deer utilizing the Cove's fields (Fox and Pelton 1973).

Because of the arthropod-borne mode of transmission of this disease, the epidemiology of hemorrhagic disease is very complex. Consequently, several aspects of the disease's epidemiology were investigated. The presence and extent of virus activity was evaluated serologically in deer and cattle. Because the manifestation of this disease is affected to a great extent by density and movement of hosts, in this case both deer and cattle, movement and density studies were conducted as described previously. The presence and abundance of the primary vector, Culicoides variipennis, was also evaluated in order to assess the risk of another major epizootic like the one that occurred in the early 1970's.

Methods and Results

Five hundred ninety white-tailed deer sera samples and 56 cattle sera samples from Cades Cove were screened at a level of 1:10 using the indirect fluorescent antibody technique (Jochim et al. 1974) and the immunodiffusion test (Kanitz 1977). Sera from 5 different deer were positive for BT viruses and/or EHD viruses (Table 27).

Three of the five seropositive deer were recaptured before and/or after the point when they were seropositive. The deer with record number 410 was first captured on November 20, 1982 and was negative for BT and EHD viruses. When recaptured on April 10, 1984 (506 days later) it was positive at a titer of 1:10 for BT and EHD viruses.

The deer with record number 418 was seropositive the first time it was captured on May 1, 1984. The deer had a titer of 1:40 for EHD virus, but was negative for BT virus. The same deer was recaptured on December 6, 1984 (219 days later) and was negative for both BT and EHD viruses.

The deer with record number 431 is the most interesting. It had the highest titer of any of the seropositive deer with a titer of 1:80 for BT virus. It was negative for EHD virus. This deer was captured both before and after this point and was negative for both viruses. This deer was first captured on November 30, 1982 and was seronegative. It was recaptured on June 15, 1984 (562 days later) and was seropositive as described. It was captured a third time on November 1, 1984 (139 days from the last capture) and was again seronegative.

Based on the serologic profiles of deer numbers 418 and 431, titers to BT or EHD viruses may disappear within 139 to 219 days. This represents approximately 4 1/2 to 7 months. However, this must be considered a crude estimate since it is based on only two deer which were seropositive at one point in time. The time at which these two deer were seropositive could represent points of rising or declining titer. Detectable titer could disappear sooner than 139 days or persist beyond 219 days.

Table 27. White-tailed deer seropositive for bluetongue and/or epizootic hemorrhagic disease viruses, Cades Cove, GSMNP, 1980-1985.

Record Number	Sex	Age class (yrs)	Virus Type and Reciprocal Titer	
			BTV	EHDV
410	M	≥1.5	10	10
411	F	<1.5	10	20
414	F	≥1.5	10	neg
418	M	<1.5	neg	40
431	M	≥1.5	80	neg

No gross lesions suggestive of hemorrhagic disease were noted in any of the five seropositive deer at the time of capture. In addition, they did not exhibit any signs of illness prior to darting.

Virus isolation was attempted from washed red blood cells collected from each animal at the time of capture and stored in an ultracold freezer. No virus was isolated.

No particular pattern is suggested by this distribution of seropositive animals since seropositive animals were found in virtually all parts of the Cove, except the far west end (Figure 17). It is interesting to note that the far west end is the only part of the Cove that in recent history has been free of cattle. However, with the low number of seropositive animals, lack of seropositive animals in the west end of the Cove is not sufficient to preclude virus activity in this area.

All seropositive deer were captured within a very short period of time. The first seropositive deer was captured on April 10, 1984 and the last seropositive deer was captured on June 15, 1984. This is a span of 66 days.

Samples were usually collected on a weekly basis in 1984 beginning in March and ending in early November. Since hemorrhagic disease in deer is most often manifested clinically in the late summer and early fall, this cluster of seropositive animals would be unusual if these titers resulted from infection during calendar year 1984. If these seropositive titers represent infection during 1983 (late summer and fall), the cluster could imply an outbreak in 1983 which went undetected.

Clinical evidence of hemorrhagic disease activity in the Cove deer herd was suspected in October, 1981. On October 5, 1981, a 2 1/2 year old female was submitted for necropsy. She had been observed along the Cades Cove Loop Road exhibiting atypical behavior. She was apparently blind and was exhibiting seizures, diarrhea, and bloody exudate from the mouth and nostrils. The necropsy revealed multifocal hemorrhages with hyperemia and vasculitis in the pulmonary artery (tunica media), heart, rumen, intestine, skeletal muscle and kidney. Multifocal sites of hemorrhage, especially in the tunica media

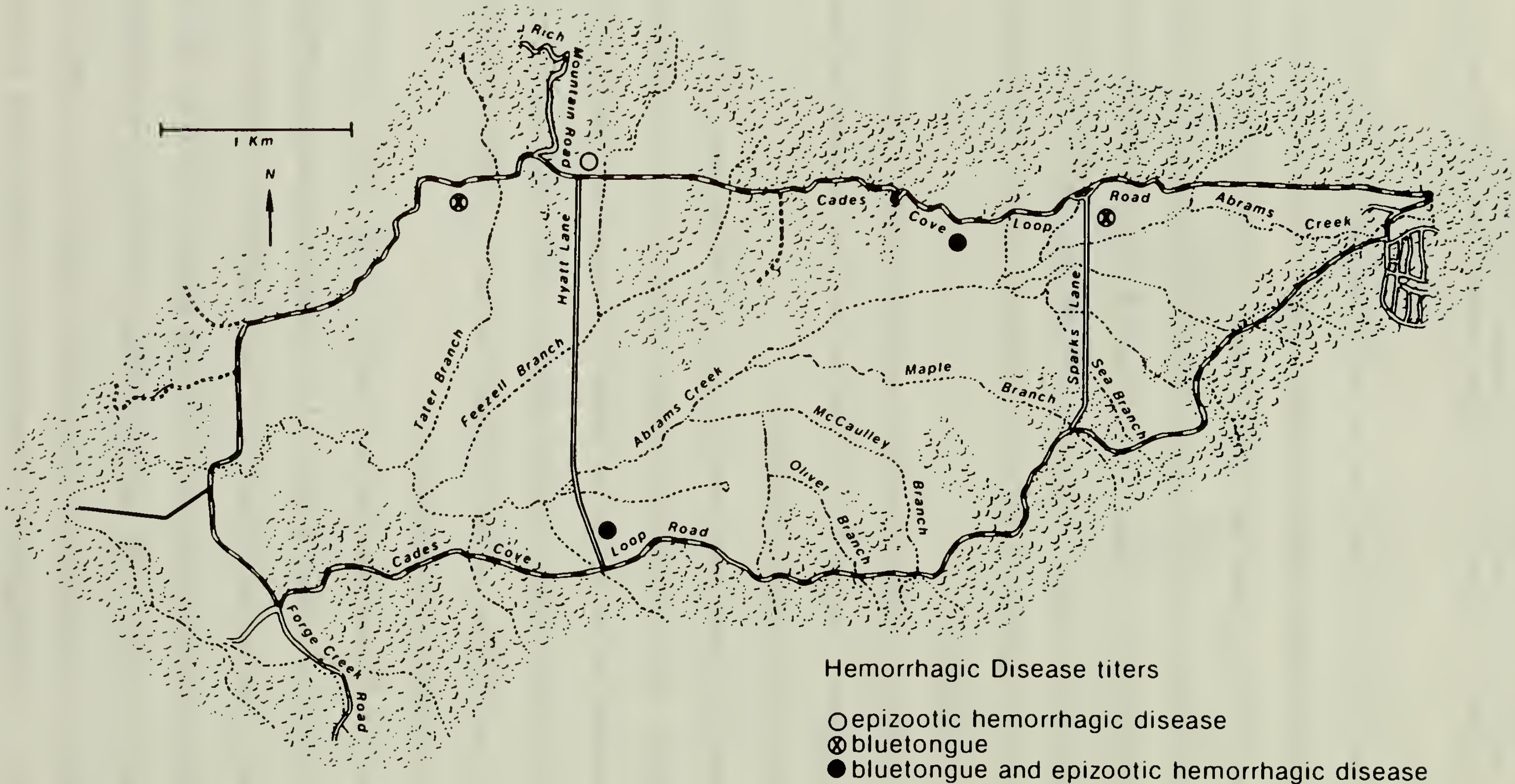

Figure 17. Darting locations of white-tailed deer seropositive disease (bluetongue or epizootic hemorrhagic disease viruses), Cades Cove, GSMNP, 1980-1984.

of the pulmonary artery, are consistent with a diagnosis of hemorrhagic disease. Virus isolation was unsuccessful however, and the deer was seronegative for hemorrhagic disease viruses. This case occurred at a time of the year when cases of hemorrhagic disease would be expected.

On August 10, 1982, a 2 1/2 year old male from the herd was necropsied after euthanasia because of aberrant behavior. Visitors had observed the deer wandering aimlessly and stumbling over objects. The deer had at least partial if not complete loss of vision and even walked into the side of a vehicle.

Upon necropsy the dental pad and a portion of the hard palate was found to be elevated, nodular, ulcerated, friable and grey in color suggesting necrosis. This lesion extended to the underlying bone. The lymph nodes draining the area were enlarged and reddened externally and grey on cut surface. Histopathic examination of tissues revealed a chronic arteritis of the dental pad, heart and lumbar skeletal musculature consistent with hemorrhagic disease. BT virus was isolated from washed red blood cells from this animal.

The vision impairment of these two deer cannot be explained. There was no histopathic evidence of lesions in the eyes, optic nerves or brains.

None of the cattle sampled were serologically positive for any of the hemorrhagic disease viruses. There was no evidence noted of clinical disease in cattle that could be directly related to hemorrhagic disease viruses. However, the number of cattle sampled was small and not collected randomly from all parts of the Cove where cattle are pastured. In addition, hemorrhagic disease virus infection in cattle is usually very mild.

Discussion

In order for an epizootic of hemorrhagic disease to occur, three main elements must be in place. Presence of one of the BT or EHD viruses is obviously needed. We have serologic and isolation evidence that at least one type of BT and possibly one type of EHD virus is present.

A second element is a dense deer population. This element is also in place as documented by the Population Dynamics portion of this study.

The third element is an appropriate vector population. Of all the Culicoides species found in the Cove, only one, C. variipennis, is known to transmit hemorrhagic disease viruses. This fly was found in very low numbers however, and consequently is probably the weakest link in the chain of elements that are required for an epizootic. The most probable reason for this situation has specific implications for habitat management in the future.

Culicoides variipennis can breed in microhabitats efficiently enough to maintain the species from year to year. When provided optimum breeding habitat, this fly can reproduce rapidly and reach very high numbers. However, optimum breeding habitat has fairly strict parameters (Wirth and Jones 1957, Jones 1961, Mullens and Rutz 1983).

The fly breeds best in still, shallow water. Optimum habitats have been found around livestock drinking troughs in the Western U.S. Shaded shallow water is less likely to produce great numbers of flies as the same water in full sun.

When the soil around the edges or the sediment on the bottom of these pools is enriched with manure, tremendous numbers of flies can be produced in a relatively short period of time.

The Cove was searched extensively for appropriate C. variipennis breeding habitat. Very few sites were found. The fencing of Abrams Creek in the mid-1970's may account for vector habitat changes which have been significant enough to prevent a repeat of the 1971 epizootic. Vector collection at several sites in the Cove resulted in very few C. variipennis being found. Details of the vector surveillance activities are contained in a separate report titled "Distribution, Abundance and Feeding Preferences of Culicoides

Flies in Cades Cove, Great Smoky Mountains National Park, 1983-1984" by R.R. Gerhardt, G.B. Wilson and L.J. Hribar.

Implications

Hemorrhagic disease is well documented as a devastating disease in white-tailed deer. This disease represents the greatest threat to the continued health and status of the Cove deer herd. Any habitat manipulation that would increase the available breeding habitat of the vector would likely increase the potential for an epizootic in the deer herd.

The implications of translocating Cove deer during the restoration project was discussed with the Southeastern Cooperative Wildlife Diseases Group in Athens, Georgia. Because hemorrhagic disease is so widespread and endemic in the Southeast, it is unlikely that Cove deer would represent an additional threat to other deer herds.

The white-tailed deer is not the best carrier of these viruses. Even if deer were viremic at the time of translocation, it is unlikely that they would be released in areas of high deer density. This would go against the philosophy of deer herd restoration.

Domestic cattle are susceptible to BT and EHD virus infections but when infection occurs, clinical disease is usually mild. Many inapparent infections occur in cattle based on serologic surveys. Domestic sheep on the other hand are also susceptible to the viruses and can experience severe disease and even death. However, it is unlikely that translocated deer would represent a major risk to domestic ruminants. If viremic deer were translocated, their natural aversion to domestic livestock would reduce the probability of spread of the viruses.

From the standpoint of hemorrhagic disease, Cove deer do not represent a major threat to domestic livestock. Domestic ruminants are more likely to contract hemorrhagic disease from other infected herds of the same type, than they are from deer.

None of the hemorrhagic disease viruses are transmissible to humans.

LEPTOSPIROSIS

Leptospirosis is an infectious disease of animals including humans, caused by bacteria in the genus Leptospira. The genus Leptospira is composed of two species, L. biflexa and L. interrogans. Leptospira biflexa is considered nonpathogenic and is associated with the environment. Leptospira interrogans includes all the pathogenic serovars and, at one time, the serovars were given species designations (e.g. L. pomona, L. grippotyphosa, etc.) (Roth 1970). Many serologically distinct serovars are known and 24 pathogenic serovars have been isolated from wildlife in the United States. Two serovars have been isolated from white-tailed deer and serologic surveys of deer have suggested infection by other serovars (Reilly et al. 1962b, Roth 1970).

Leptospires can infect a wide variety of animals and can survive for long periods under the right environmental conditions outside hosts. These bacteria require moist, slightly alkaline soils and low flow, slightly alkaline waters (Diesch and Ellinghausen 1975, Galton et al. 1962, Roth 1970).

Leptospires can be transmitted from their animal or environmental reservoirs to new hosts through contaminated food and water. The motile bacteria can enter through abraded skin or mucous membranes as the animal wades through or drinks contaminated waters or eats contaminated food (Diesch and Ellinghausen 1975).

Once a host is infected, the bacteria commonly spread throughout the body via the blood stream during the first week. During this period, the host is often febrile but may not show any other sign of illness. Also during this hematogenous phase, the organism may become established in a variety of tissues in the body. The most important ones are the spleen, liver and especially the kidneys. If the organisms damage these organs, more severe clinical disease may be seen.

Clinical signs of leptospirosis in white-tailed deer are based on limited experimental infections where only the pomona serovar was used. Other than transient fever, the other signs of clinical leptospirosis include anorexia, weakness, anemia, hemoglobinuria, icterus and death (Shotts 1981a, b, Ferris et al. 1960, Reilly et al. 1962a, Roth 1962, Roth 1970, Trainer et al. 1961). Abortion has resulted from experimental infection and has been documented in at least one naturally infected deer (Trainer et al. 1961, McGowan et al. 1963).

Pathologic manifestations are often limited to interstitial nephritis in naturally occurring infections (Abdulla et al. 1962, Roth et al. 1964). Experimental infections have also resulted in hepatitis and hemorrhages (Ferris et al. 1960, Roth 1970).

Leptospires may persist the longest in renal tissue which allows an efficient portal of exit via the urine. Shedding of organisms in the urine usually begins during the second week of infection and may continue for long periods depending on the host and serovar involved. Urine of carrier animals constitutes the primary source of infection for other hosts (Shotts 1981a, b).

The interaction of leptospires and hosts is complex. Infection resulting in clinical disease, followed by a carrier state is only one possible outcome of exposure. However, this sequence of events is much less common than inapparent or subclinical infection. Animals may become infected and develop circulating antibodies to a particular serovar without showing obvious clinical signs. Some hosts may become seropositive without shedding organisms. Conversely, in some well adapted host-serovar relationships, a host may become infected, shed organisms in the urine and remain seronegative (Roth 1970).

Some leptospiral serovars are associated with particular host species. In general, the better adapted the serovar is to a particular host, the less damage it will do to the host. Consequently, a relatively healthy infected host that is shedding organisms allows the greatest chance of survival for the organism. This is called a maintenance host.

A wild animal can be a maintenance host for one or more leptospiral serovars, but develop clinical signs and even die if infected by a different serovar to which it is not well adapted. In addition, the same serovars in the same hosts may exhibit differences in adaption on a geographic basis (Diesch and Ellinghausen 1975, Roth 1970, Shotts 1981a, b).

The most extensive research regarding leptospirosis in white-tailed deer has been serologic surveys. The earliest surveys were conducted in the late 1950's and 60's because of concern regarding the potential transmission of leptospirosis from wildlife, especially deer, to domestic animals, cattle in particular. Leptospirosis can be a significant disease of cattle causing fever, hemorrhages in the skin and mucous membranes, malaise, anorexia, icterus, anemia, hemoglobinuria, and evidence of hepatitis and renal failure in some cases. Abortions and stillbirths are a consistent sign of leptospirosis in cattle. Infertility may also occur due to chronic endometrial changes (Hanson 1980).

Many early studies concentrated on the antibody titer prevalence of only a few serovars. The serovars most important in cattle are pomona and hardjo. Consequently, these received the majority of the attention. Serologic surveys for leptosporosis in white-tailed deer are summarized in Table 28.

Grippotyphosa and pomona serovars are commonly reported stimulating antigens associated with white-tailed deer (Shotts 1981a, b). This could be a reflection of the most common leptospires deer come in contact with, or reflect the emphasis in serologic surveys on the serovars important to domestic livestock. The latter case could be especially true of the pomona serovar.

Although deer can be reservoirs of leptospirosis, numerous small mammals are also known to be reservoirs especially of grippotyphosa and pomona serovars (Roth et al. 1964). It has been postulated that these small mammal reservoirs could actually act as a source of "booster" antigen for deer. Following an initial infection, deer may have their immunity

Table 28. Summary of serologic surveys for leptospirosis in white-tailed deer

Survey Number	Number of Deer Sampled	Location of Survey	Total % Positive	References
1	187	MINNESOTA	16	Wedman and Driver 1957
2	224	OHIO	19	Anonymous 1958
3	586	WISCONSIN	28	Trainer and Hanson 1960
4	628	MASSACHUSETTS	0	Reynolds and Smith 1958
5	403	10 SOUTH-EASTERN STATES	1.7	Shotts et al. 1958
	69	LOUISIANA	4.9	
	68	ALABAMA	2.9	
	53	KENTUCKY	1.9	
	105	GEORGIA	0.9	
6	1544	9 SOUTH-EASTERN STATES	19	Shotts and Hayes 1970
	351	VIRGINIA	30.8	
	231	MARYLAND	21.2	
	255	KENTUCKY	17.2	
	152	ALABAMA	13.9	
	54	TENNESSEE	13	
	250	GEORGIA	12.2	
	69	FLORIDA	11.6	
	117	ARKANSAS	8.5	
	65	MISSISSIPPI	7.7	
7	578	SEVERAL STATES	8.3	Harrington 1975
		ARIZONA		
		INDIANA		
		NORTH CAROLINA		
		OKLAHOMA		
		TEXAS		
8	3673	ILLINOIS	15.9	Andrews et al. 1964 Ferris et al. 1958 Ferris et al. 1961a Ferris et al. 1961b
9	369	IOWA-NEBRASKA	9.5	Haugen 1967
10	103	NEW YORK	22.3	Reilly et al. 1962b
11	190	MICHIGAN	26.3	Youatt et al. 1959
12	392	ONTARIO	27	Abdulla et al. 1962
	518	TENNESSEE	22.8	Wathen and New. 1986 (current study)

stimulated through repeated exposure to leptospires shed by small mammal reservoirs living in the same habitat (Shotts 1981a, b).

Methods and Results

Five hundred ninety serum samples from 518 white-tailed deer were tested for the presence of antibody to 5 L. interrogans serovars (pomona, hardjo, grippotyphosa, canicola and icterohemorrhagiae). One hundred eighteen deer (22.8%) were positive for one or more of the serovars.

A microagglutination test was used to test the sera. Samples were screened at a dilution of 1:250. Titers of 1:100 or greater by the microagglutination test are generally considered significant and of diagnostic importance (Diesch et al. 1976, Hanson 1982). Titers of at least 1:250 were found for all serovars tested except grippotyphosa (Table 29).

The distribution of seropositive deer by age class and sex is displayed in Table 30. In some instances, age and sex data were not recorded at the time of darting and are considered missing values. Only deer with recorded age class and sex were used for statistical analysis.

The FUNCAT (SAS 1982b) statistical program was used to compare the age class and sex distribution of the deer that were seropositive. Adult ($\geq$ 1.5 years) males were much more likely to be seropositive than females of any age or males less than 1.5 years old. This association was statistically significant ($P=0.001$).

No clinical disease was found during the study period which could be attributed to leptospirosis. Leptospire culture was not attempted from the few deer available for necropsy.

Figure 18 displays the darting sites of deer found to be positive for at least one leptospire serovar. The site of darting was not recorded or incompletely recorded on some data sheets.

The distribution of seropositive deer is generally uniform with seropositive deer being found in all parts of the Cove. The clusters associated with the lanes and at the west

Table 29. Occurrence of antibody titer to leptospirosis (4 serovars) in white-tailed deer, Cades Cove, GSMNP, 1980-1985.

	hardjo			pomona			icterohemorrhagiae			canicola		
Reciprocal Titer	250	500	1000	250	500	1000	250	500	1000	250	500	1000
Number Positive	48	16	6	21	22	0	19	1	0	2	0	0
Total	70			43			20			2		
% positive	13.5			8.3			3.9			0.4		

Table 30. Frequency of white-tailed deer seropositive for leptospirosis (4 serovars) by age class and sex, Cades Cove, GSMNP, 1980-1985.

Sex	Age class (years) <1.5		≥1.5			
	Frequency[a)]	Proportion %	Frequency	Proportion %	Total	Proportion %
Males	12 of 54	22.0	43 of 115	37.1	55 of 169	32.5
Females	13 of 64	20.3	48 of 230	20.9	61 of 294	20.8
Total	25 of 118	21.2	91 of 345	26.4	116 of 463	25.1

a) Number of positive deer in age class, sex category compared to number of deer sampled in the same age class, sex category. Data sheets on 55 deer were missing age or sex data and were not useable for comparisons.

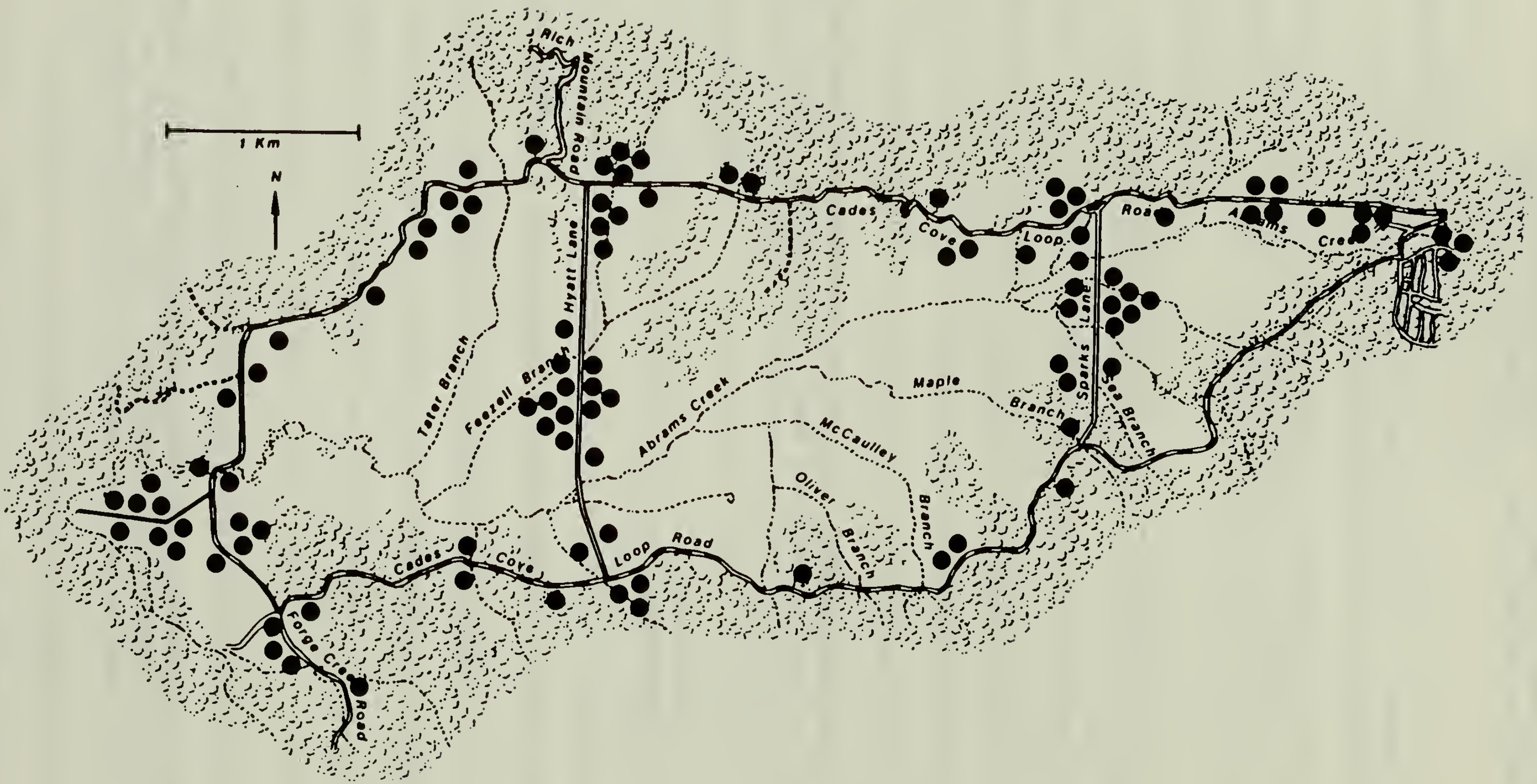

Figure 18. Darting location of white-tailed deer seropositive for leptospirosis, Cades Cove, GSMNP, 1980-1984.

end of the Cove probably reflect the topography of these areas which allowed better darting opportunities. These clusters do not necessarily represent nidi of infection.

Serum from 56 cattle were tested for the presence of antibody to the same five leptospiral serovars. No antibody was found to grippotyphosa, icterohemorrhagiae, or canicola serovars. Two animals were positive for the pomona serovar with titers of 1:800 and 1:3200. However, 28 of the 56 animals (50%) were positive for the hardjo serovar. In addition, titers were very high in many of the seropositive cattle.

Ten of the cattle had titers to serovar hardjo greater than 1:3200. Eleven had titers of 1:1600 and 5 had titers of 1:800. Two cows had titers of 1:400. Physical exams were not conducted at the time of blood collection but no gross signs of illness were noted.

Discussion

From the aspect of this study, the most important serologic surveys described in the literature are ones with large sample sizes and/or those where samples were collected from relatively small geographic areas. In addition, those surveys that included multiple serovars better reflect the status of leptospirosis in deer than those which focused on only one or two serovars. Consequently, five surveys included in Table 28 (6,7,8,9 and 10) give the best basis for comparison with the current study. The prevalence of serovar antibody within the subpopulation of seropositive deer from each of these surveys is displayed in Table 31.

Serovar pomona consistently appeared as one of the most common stimulating antigens in each survey. It was the most common serovar found in two of the five surveys and was the second most frequent serovar found in the other three surveys. Serovar grippotyphosa also occurred very frequently and was the most common stimulating antigen in two of the five surveys. Serogroup habdomadis was the most common stimulating antigen in the New York survey with 56.6% of seropositive deer being positive for this serogroup. Autummalis was frequently found in three surveys (22,27.1 and 28.6%) and serovar icterohaemorrhagiae was found at a level of 17 and 17.5% in two surveys.

TABLE 31. Frequency of serovar antibody in subpopulations of seropositive white-tail deer.

Survey Number	Location of sample	pom.	aut.	aus.	bal.	gri.	heb.	can.	ict.	pyo.	hyo.	geo.	sej.	bat.	har.	Reference
6	9 Southeastern States	22.6	0.5	4.0	1.1	56.6		7.0	2.7	1.6	1.4	1.1	0.8	0.5		Harrington 1975
7	5 States	52.1	27.1	18.8	16.7	12.5	12.5	6.3	2.0							Shotts & Hay 1970
8	Illinois	43.0			8.7	38.1		2.6	0.7				4.4			Andrews, et 1964 Ferris, et a 1958 and 196
9	Iowa/ Nebraska	37.1	28.6		11.4	40.0							8.6		11.4	Haugen, 1967
10	New York	34.9	22.0	0	4.5	22.0	52.4	8.5	17.5				0	0		Reilly, et a 1962b
	Tennessee Cades Cove GSMNP	36.4				0		1.7	17.0						59.3	Current Stud Wathen, et a

1. See Table 35
2. The number of positive samples for each serovar was divided by the total number of positive samples for any serovars and expressed as a percent of all positives. Because some animals may have titers to more than one serovar, the percentages may exceed 100%. pom=pomona, aut=autummalis, aus-australis, bal=ballum, gri=grippotyphosa, heb=hebdomadis, can=canicola, ick=icterohaemorrhagiae, pyo=pyogenes, hyo=hyos, geo=georgia, sej=sejrol, bat=bataviae, har=hardjo.
3. Arizona, Indiana, North Carolina, Oklahoma, Texas
4. Virginia, Maryland, Kentucky, Alabama, Tennessee, Georgia, Florida, Arkansas, Mississippi.

In the current study, serovar pomona antibody was found in 8.3% of all deer sampled and in 36.4% of the seropositive deer. Other studies that tested for pomona antigen found a range of 0 (Massachusetts) to 28% (Wisconsin) of deer sera positive with an average of 12.2% (Table 35).

The distribution of deer seropositive for the pomona serovar is displayed in Figure 19. There is an association between high titers and permanent cattle pastures along Sparks Lane and the southern end of Hyatt Lane (see Figure 10).

The cluster of deer with high titers to serovar pomona at the west end of the Cove is interesting since there are no cattle in this area. There are two possible explanations for this cluster.

Male deer, particularly adults ($\geq$ 1.5 years) were found to have the largest annual home range (263.2 ha) compared to adult females and subadult males and females (Table 13). This could easily bring adult male deer from the west end of the Cove into contact with the cattle herds. In addition, adult male deer may be more efficient in spreading leptospirosis than the other age and sex classes.

Deer in general may be responsible for spreading leptospirosis greater distances than the small wild mammal reservoirs because of their natural movements. Because leptospires are shed primarily in the urine, and because male deer use urine to mark territories and attract females during the rut, a single infected male could magnify an infection within a population. Other male deer in particular, are drawn to these urine marked areas. One study has shown that urine containing leptospires is excreted in the same spots within a territory (Litvin and Golubev 1982).

Consequently, there does not need to be widespread contamination of a habitat for leptospirosis to be transmitted. The attraction of deer to discrete foci of contamination would be an efficient way to assure exposure of new hosts. Litvin and Golubev (1982) have shown that persistent excretion of urine at these discrete sites decreases the acidity of the soil, thus creating more favorable conditions for the survival of leptospires in the soil.

These factors could explain the significantly higher prevalence of leptospiral antibody (P=0.001) found in adult male deer compared to the prevalence in the other age and sex classes.

A second explanation of the distribution of pomona serovar antibody in the Cove could be spread of this serovar to deer from a different wild mammal host. The pomona serovar has been found in a variety of wild mammals including raccoon, opossum, skunk (spotted and striped), red fox, mice (house, old field, deer, and western harvest), bobcat and woodchuck (Diesch and Ellinghausen 1975). Most of these species are present and, in some cases, plentiful in the Cove. The prevalence of pomona serovar titers in the Cove could be related to one of these other reservoirs.

A factor that could be related to a small mammal reservoir in the west end of the Cove is the close proximity of habitat that could represent a nidus of infection. Figure 19 contains an area labelled "Swamp". In this area, Abrams Creek, the main drainage of the Cove, slows in its course and becomes very shallow. The swampy conditions that result may represent a microenvironment for extracorporeal leptospires. Leptospires, in order to survive outside the host, need still water or water soaked soils, instead of rapidly moving water which is characteristic of most of the other drainages of the Cove.

In addition, because of the swampy nature of this area, it has not been cleared for pasture. Since it is brushy and overgrown and surrounded by meadows that are mowed periodically, this area is excellent habitat for small mammals. Consequently, this area could be a nidus of infection because of its potential as a small mammal habitat where leptospirosis may cycle. The role of adult male deer could still be involved in the spread of infection from this nidus.

The most striking difference between this study and previous serologic surveys was the high prevalence of antibody titer to serovar hardjo. Of all deer sampled, 13.5% were positive for this serovar. Of seropositive deer, 59.3% were positive for serovar hardjo. It was the most frequent serovar found in the Cades Cove deer herd.

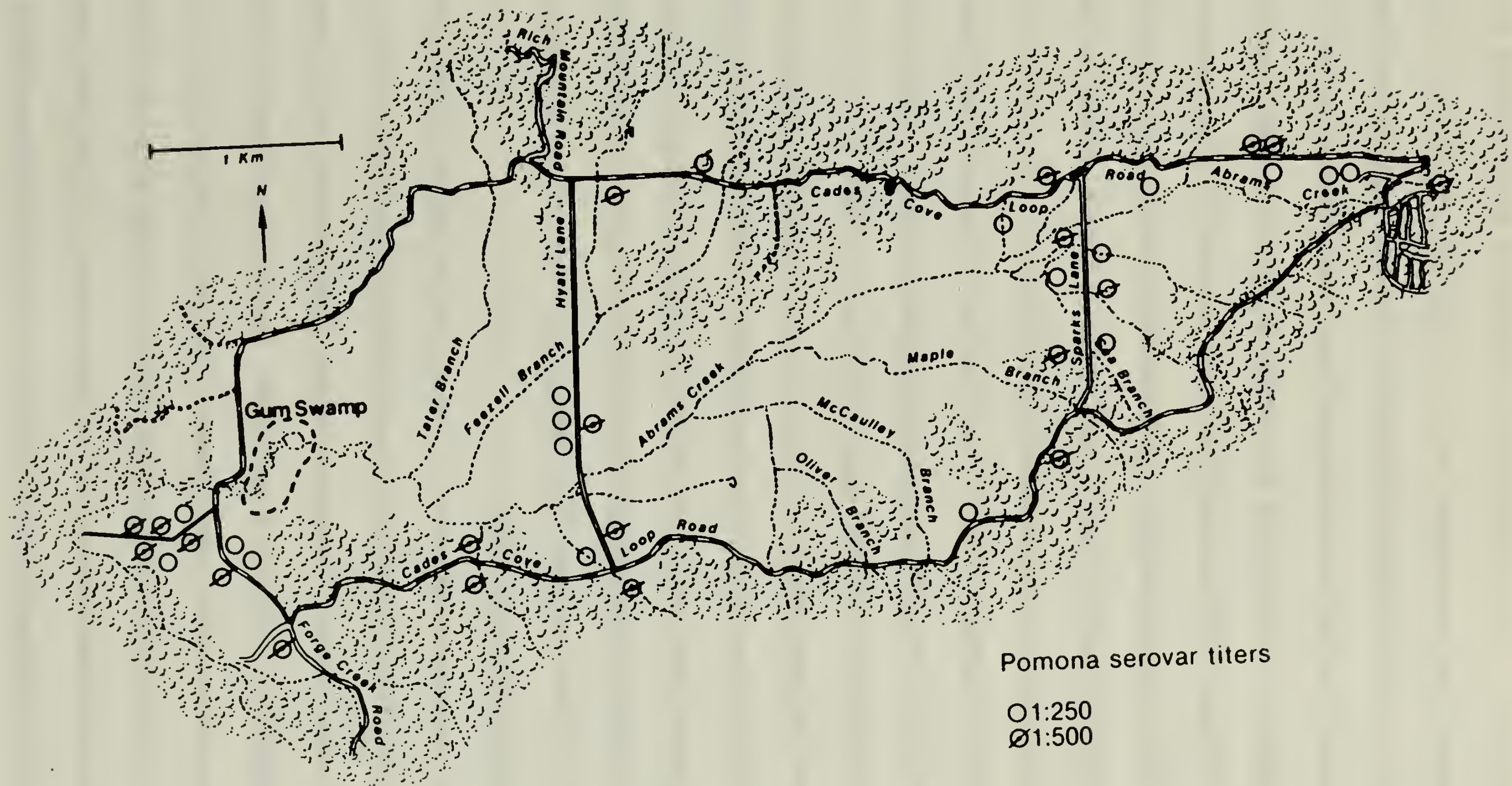

Figure 19. Darting locations of white-tailed deer seropositive for leptospirosis (serovar pomona), Cades Cove, GSMNP, 1980-1984.

Only one other survey (Haugen 1967) specifically reports finding serovar hardjo titers in white-tailed deer. In this survey, 1.1% of 369 deer sera collected in Iowa and Nebraska were positive for serovar hardjo.

Serovar hardjo is in the hebdomadis serogroup. Two serologic surveys report testing deer sera for habdomadis without indicating specific serovars (Harrington 1975; Reilly et al. 1962b). Harrington (1975) found 6 of 431 samples (1.4%) from Oklahoma positive for the habdomadis serogroup. Reilly et al. (1962b) reported 11.7% of 103 deer sera positive for hebdomadis. When this work was done, serovar hardjo had only recently been isolated from cattle (Roth and Galton 1960). In the study by Reilly (1962b), 52.4% of leptospirosis positive deer were seropositive for hebdomadis (Table 38).

Serovar hardjo is strongly associated with cattle. In the United States, serovar hardjo has been isolated from cattle and humans (Hanson 1981). This serovar has not been isolated from a wildlife host (Diesch et al. 1976, Hanson 1982).

In most cases, serovars hardjo and pomona are apparently transmitted directly among cattle whereas evidence of other serovars infecting cattle are likely extensions of wildlife infections (Diesch et al. 1976). Leptospires exhibit a species preference and cattle are considered the natural carrier host of serovar hardjo (Blood et al. 1983, Diesch et al. 1976, Hanson 1982). Cattle can shed leptospires in the urine for over one year under experimental conditions (Thiermann 1982).

Positive titers to serovar hardjo are the most common serologic finding in cattle in some parts of the U.S. (Blood et al. 1983, Diesch 1983, White and Sulzer 1982). There is also evidence that hardjo serovar infection is rather widespread across the country. Of 66,522 cattle sera collected from 18 states, 7.2% were serovar hardjo reactors. By comparison, 6.5% were reactors to serovar pomona (Diesch et al. 1976).

Infertility in cattle has frequently been associated with enzootic hardjo serovar infections. Abortions and, particularly, low conception rates are frequently seen in beef and dairy cattle infected with hardjo serovar (Diesch et al. 1976, Hanson 1977). Serovar hardjo titers have also been associated with lactation failure in beef herds (Blood et al. 1983).

Figure 20 shows the distribution of deer seropositive for the hardjo serovar. The distribution is generally uniform but there may be a disproportionate number of deer with high titers associated with the two lanes. Sparks Lane transects pastures used permanently for cattle as does Hyatt Lane at its southern end (Figure 10). Since cattle are the primary reservoir host for the hardjo serovar, this association is not surprising.

The cluster of deer with high titers at the north end of Hyatt Lane is associated with pasture that is used seasonally (temporarily) as cattle pasture. These pastures are most often used in the winter. Exposure potential for deer may be increased during the winter as they compete for hay resources and are perhaps drawn to salt blocks. This would increase their contact with areas contaminated by cattle urine.

Serovar hardjo infection is an emerging human health problem in the United Kingdom where it is referred to as cattle-associated leptospirosis. It produces a milder form of leptospirosis with "flu-like" symptoms, fever, severe headache and mental confusion as the most common presenting signs. In a few cases, lymphocytic meningitis, hepatorenal failure, and, rarely, death may occur. In the United Kingdom in 1983, 80% of patients were dairymen or cattle herdsmen (Waitkens 1985). This same occupational hazard has been documented in the U.S., with outbreaks of human illness due to hardjo serovar occurring in owners and handlers of infected dairy cows. The hardjo serovar was first isolated from a human in the U.S. during these recent outbreaks (White and Sulzer 1982).

The distribution of the icterohaemorrhagiae and canicola serovars illustrated in Figures 21 and 22 respectively does not show any striking pattern. The icterohaemorrhagiae serovar has been isolated from all the wild mammals listed with the pomona serovar except bobcats. In addition, it has been isolated from nutria, muskrat and rats (Norway, Pacific, roof, and cotton). The canicola serovar has been isolated from raccoons and spotted and striped skunks (Diesch and Ellinghausen 1975). Although these

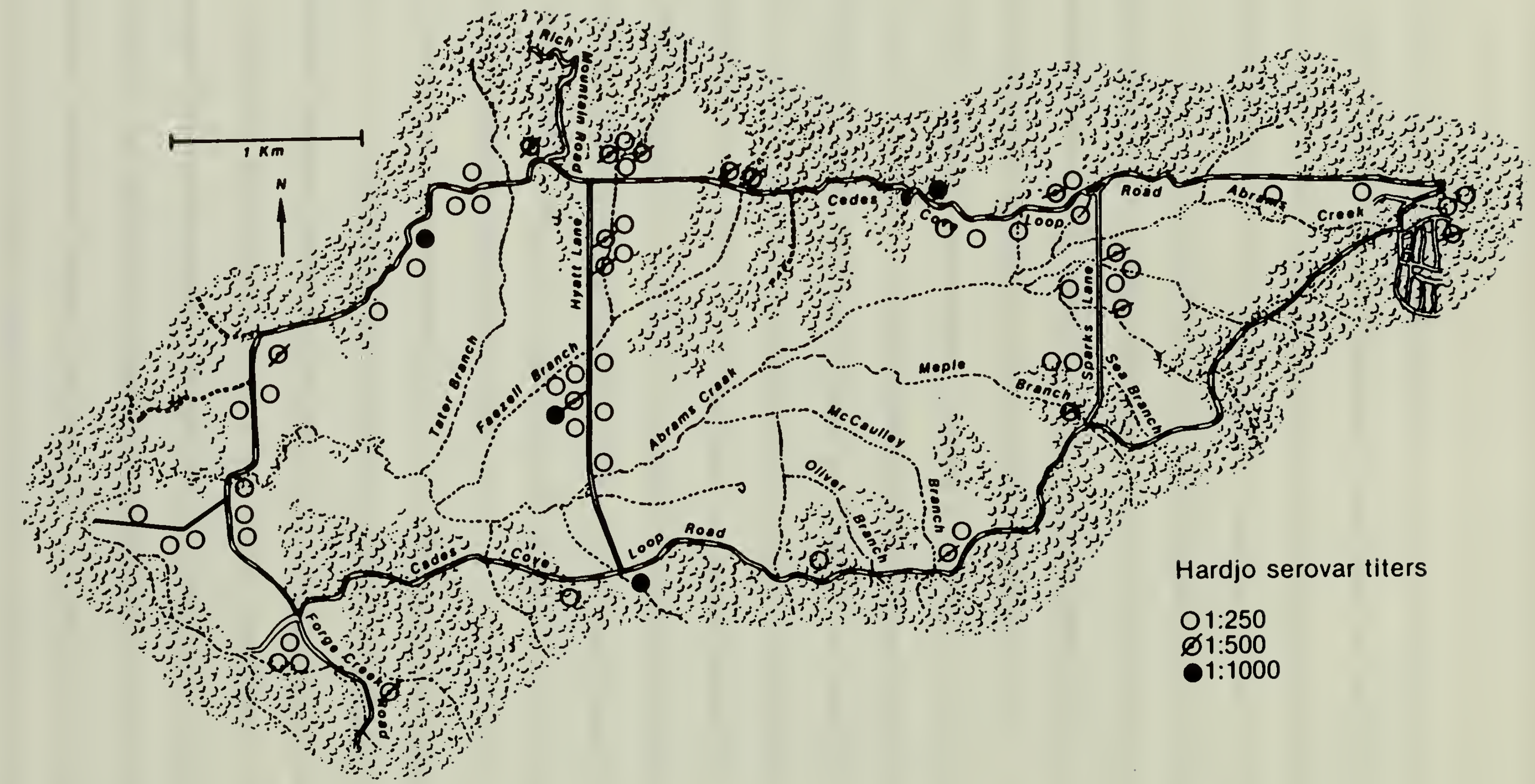

Figure 20. Darting locations of white-tailed deer seropositive for leptospirosis (serovar hardjo), Cades Cove, GSMNP, 1980-1984.

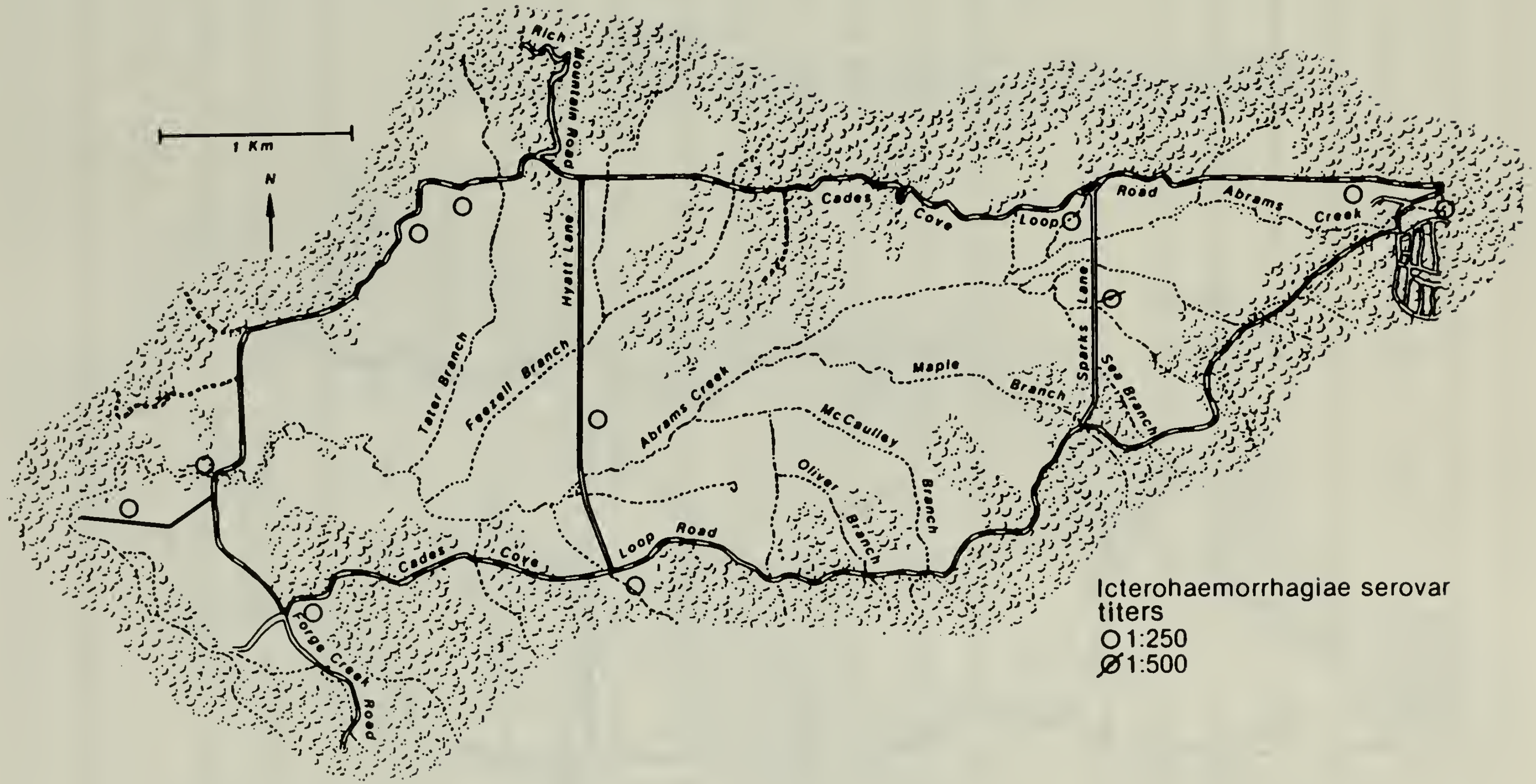

Figure 21. Darting locations of white-tailed deer seropositive for leptospirosis (serovar icterohaemorrhagiae), Cades Cove, GSMNP, 1980-1984.

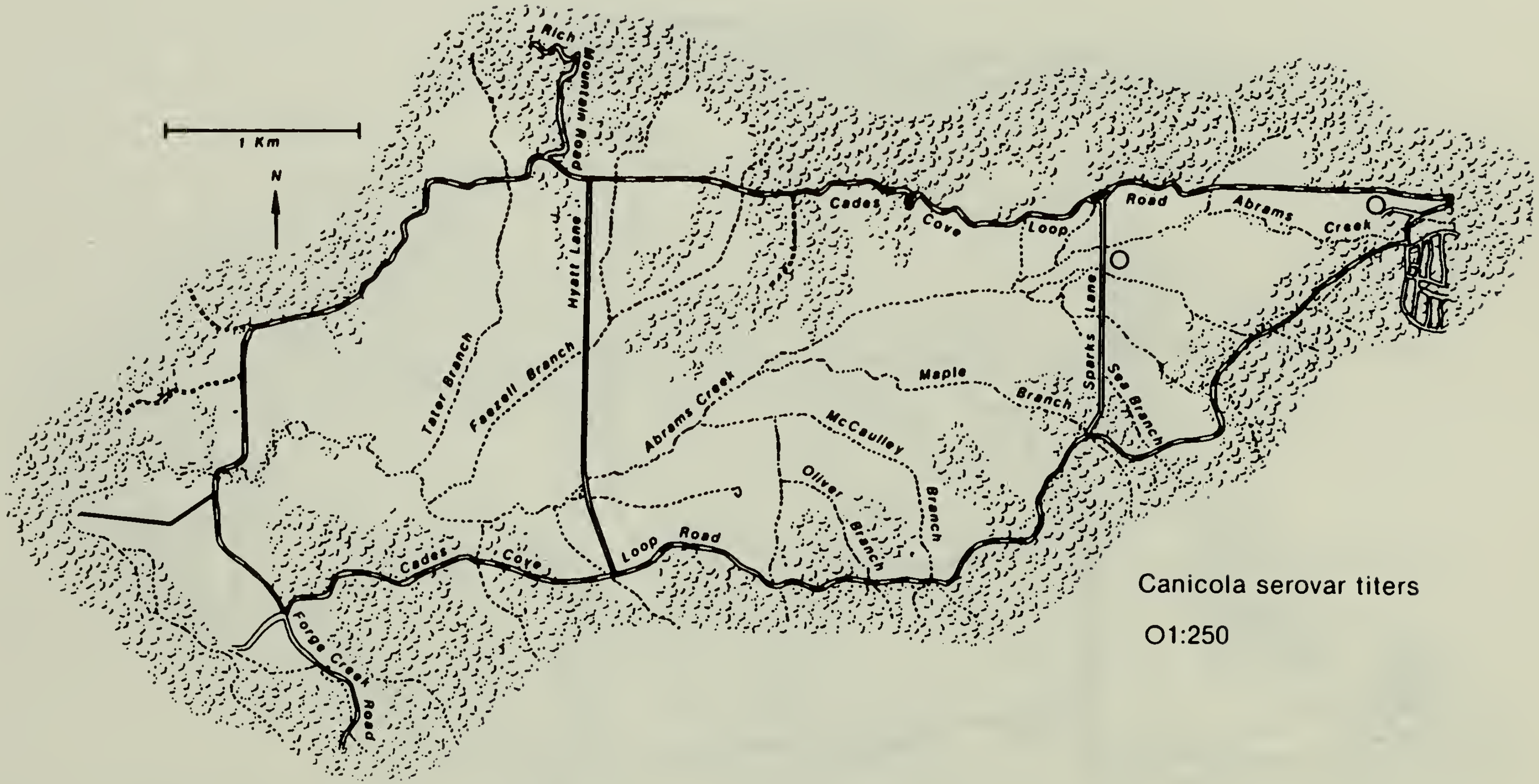

Figure 22. Darting locations of white-tailed deer seropositive for leptospirosis (serovar canicola), Cades Cove, GSMNP, 1980-1984.

two serovars have also been isolated from cattle, the distribution of antibody in deer could be explained as easily by occasional exposure of deer to other wild mammal reservoirs.

A final finding in the leptospirosis survey of the Cove deer herd is the absence of evidence of grippotyphosa serovar activity. Shotts and Hayes (1970) found that serovar grippotyphosa alone represented 56.6% of the total serologic reactions in 1,544 deer from nine southeastern states. Titers have been found in all serologic surveys of white-tailed deer when testing included the grippotyphosa serovar (Table 38). Antibody prevalence has ranged from 1.1% (Harrington 1975) to 13.6% (Shotts and Hayes 1970) with an average of 5.1%.

Implications

Leptospirosis does not probably cause death in white-tailed deer very often, and most infections are probably mild clinically. The infertility and lactation problems documented in cattle from serovar hardjo infection have not been documented in deer. Consequently, the risk of leptospirosis to the Cove deer herd appears minimal unless serovar hardjo is partly responsible for the low productivity of the herd. It could theoretically play a role in neonate mortality if it is capable of causing lactation failure in does. This question deserves further investigation.

Deer are capable of spreading leptospirosis to other parts of the Cove, other areas of the Park, and to areas outside the Park. This latter situation may occur via natural migration, dispersion, or by translocation.

The pomona, icterohaemorrhagiae and canicola serovars are probably so widespread in wildlife that introduction via deer is a minimal risk. However, if serovar hardjo is shed by deer, it could infect previously unexposed wild species and potentially become established in a wildlife reservoir. If shedding does occur, domestic livestock both inside and outside the Cove could be at risk.

All serovars implicated in the Cove deer herd have zoonotic potential. The humans at greatest risk would be Park personnel, scientists, and students who would have direct contact with deer or other wildlife. Potential modes of exposure would be via urine, blood during a bacteremic phase, or possibly via tissues handled during a necropsy. A secondary mode of transmission would be contact with contaminated water or soil. Insects are not important vectors of leptospirosis.

Risk of infection to visitors is minimal. They are unlikely to come in contact with wildlife to the extent necessary for exposure to occur. In addition, most visitors will not come into contact with water in Cades Cove. Those who do are most likely to contact fast flowing water, as at Cable Mill.

Special consideration should be given to the endemicity of leptospirosis before habitat manipulations are undertaken which would increase areas of standing water. Plans that would increase visitor access to existing areas of possible leptospirosis contamination should be considered carefully.

BOVINE VIRUS DIARRHEA

Bovine virus diarrhea (BVD) is an infectious, contagious disease of cattle characterized clinically by an acute, erosive stomatitis, gastroenteritis and diarrhea. Although the infection rate in cattle populations is high based on serologic surveys, clinical manifestation of the infection is low (Blood et al. 1979).

Clinical manifestation of infection includes ulceration and necrosis of the mucous membranes of the lips, tongue, cheek, pharynx, esophagus, small intestine, and cecum. Other clinical signs associated with these lesions include nasal discharge and excessive salivation. Fever, leucopenia, depression, dehydration and abortion are also seen in cattle (Richards 1981).

Only one possible epizootic of this disease has been reported in deer. This outbreak occurred in 1955 in North Dakota and affected white-tailed and mule deer (<u>Odocoileus hemionus</u>). There was an association between affected deer and a simultaneous epizootic in cattle (Richards 1958). As this outbreak continued over a three year period, there was evidence that clinical manifestation of the disease changed from acute symptoms to a more chronic disease. Healed lesions and other evidence of recovery were observed.

Serologic surveys of white-tailed deer populations in New York and Tennessee have reported BVD titers. Studies in New York conducted in 1964 and 1967 reported 3 percent and 6 percent BVD antibody prevalence respectively (Friend and Halterman 1967, Kahrs et al. 1964, Karstad 1981). A serologic survey of hunter killed deer in Fayette Co., Tennessee was conducted from 1981 to 1985. During this period 351 deer were sampled and 7 (2%) were serologically positive for BVD (Linnabary and Houston 1985). Except for the North Dakota mucosal disease epizootic, clinical cases of BVD have not been reported in deer. The BVD virus was isolated from a white-tailed doe from Habersham County, Georgia in 1977 (V.F. Nettles, personal communication) and from a buck from Cades Cove, GSMNP, in 1982, which will be discussed later.

Methods and Results

Of the 518 deer sampled in Cades Cove between 1980 and 1985, 27 (5.2%) were serologically positive for BVD. Titer was determined by the indirect fluorescent antibody technique as described by Potgeiter and Aldridge (1977). A titer of 1:10 or greater was considered positive.

The percent antibody prevalence by year is displayed in Table 32 and age class and sex distribution of positive deer is displayed in Table 33. Darting locations of the 27 positive animals is illustrated in Figure 23.

Only three of the cattle were serologically positive for BVD. In addition, titers were low with one each reacting at 1:5, 1:10 and 1:20. BVD vaccine had not been used extensively in this herd and no vaccines had been given for approximately 18 months prior to collection of blood.

Table 32. Percent of BVD seropositive white-tailed deer by year, Cades Cove, GSMNP, 1980-1985.

Year	Number Sampled	BVD Positive	Percent Positive
1980	50	3	6
1981	124	8	6.5
1982	109	3	2.8
1983	104	6	5.8
1984	170	7	4.1

Table 33. Distribution of BVD seropositive white-tailed deer by age class and sex, Cades Cove, GSMNP, 1980-1985.

Sex	Age class (year)		Total
	<1.5	>1.5	
Male	1	5	6
Female	6	15	21
Total	7	20	27

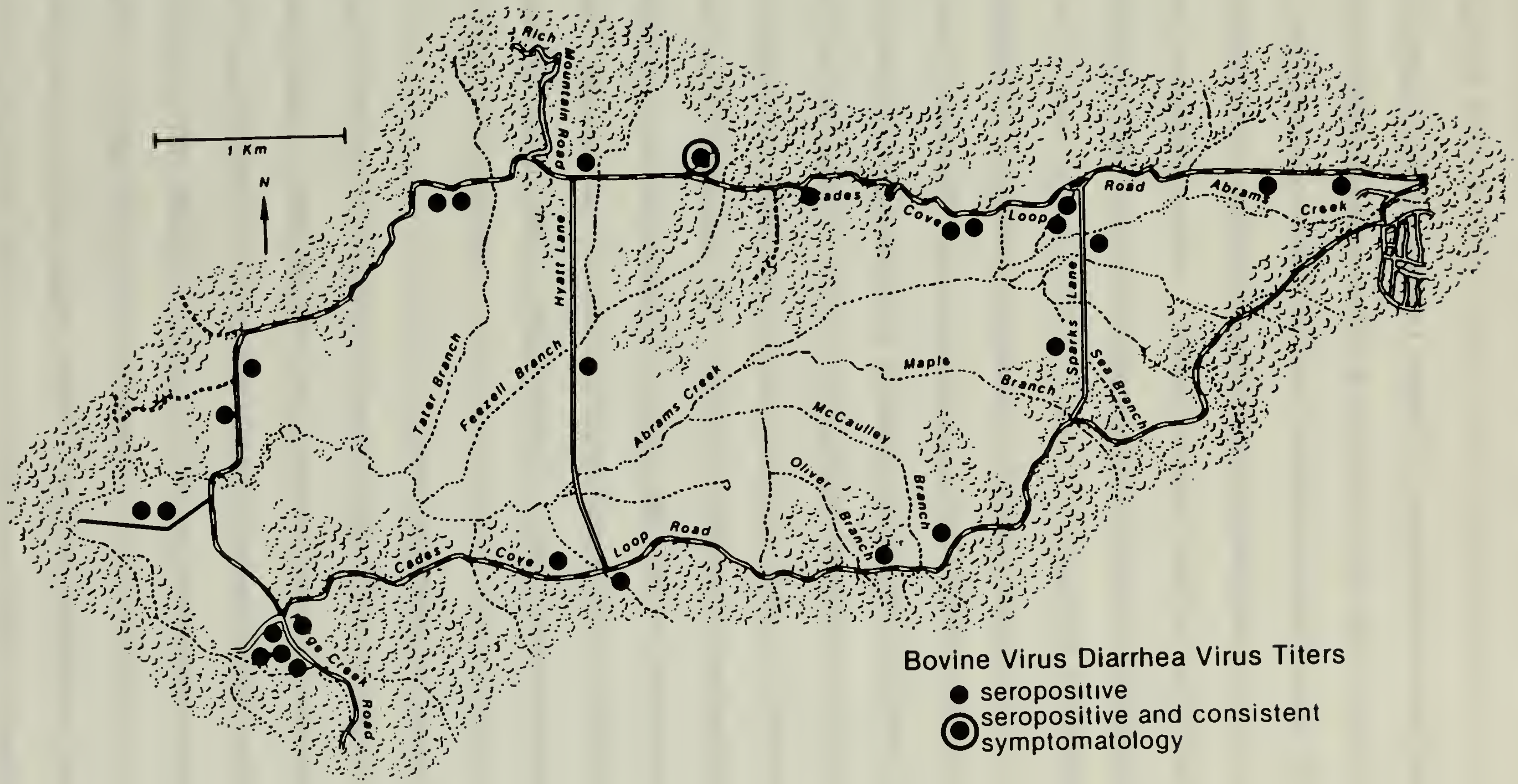

Figure 23. Darting locations of white-tailed deer seropositive for bovine virus diarrhea virus, Cades Cove, GSMNP, 1980-1984.

Discussion

Clinical BVD in white-tailed deer has been rarely reported. The mucosal disease epizootic in white-tailed and mule deer in North Dakota exhibited some symptoms suggestive of BVD in cattle and other lesions and symptoms which differed from BVD infection in cattle. The agent was not specifically identified (Richards et al. 1956).

Deer affected by the North Dakota agent varied from poor to excellent condition. Animals were weak, lacked wariness toward humans, exhibited impaired vision and hearing, and some had convulsions. A few cases observed in the field resembled furious rabies in ruminants (Richards 1956).

Field behavior of these cases was characterized by a frenzied state, charging moving objects and striking with the forefeet and butting with the head. Evidence of head injuries was observed, such as mutilation of antlers, hyperemic and darkened turbinates and clotted blood and mucus filling the nasal cavity (Richards et al. 1956, Richards 1956). Biting was not observed in these deer and at least one male examined for rabies was negative.

Experimental infection of two white-tailed deer from clinically affected mule deer captured in the wild resulted in anorexia, depression, lameness, severe diarrhea, with mucus and flecks of blood, a pronounced cough and death in one animal. The second animal experienced only lameness, soreness of the flank and abdomen and reduction in food intake for a two month period. This deer did not die, but had progressive weight loss and a roughened hair coat (Richards et al. 1956).

Post mortem lesions from naturally and experimentally infected deer consisted of hyperemic and darkened turbinates, petechial and/or ecchymotic hemorrhages of the pharynx, frontal sinuses, larynx, trachea, duodenum, jejunum, ileum, cecum, colon and rectum. Hemorrhages were also seen on the epicardium. Erosions and ulcerations were seen throughout the gastrointestinal tract except for the rumen and omasum. The pyloric region was the most consistently affected. Hemorrhage and necrosis were most pronounced in the duodenum and jejunum (Richards et al. 1956). Abortions, stillbirths and neonatal mortality was observed in does experimentally infected with the North Dakota agent (Richards 1958).

Two suspected clinical cases of BVD occurred in deer in Cades Cove during the study period. On December 20, 1982, an adult male was darted and was too lame to rise in response to being darted. After immobilization and examination, the deer was found to have a swollen left rear fetlock. He had a malodorus breath due to a necrotic, ulcerated area on the roof of the mouth. The buck was euthanized and a complete necropsy was performed. Gross findings revealed that the medial claw of the right hind foot was swollen and ulcerated around it's entire circumference near the P_1-P_2 joint. A 5 mm length of wire was embedded in the subcutaneous tissue at the ulcerated site.

A 5 cm long, 2 cm deep cavitation was present in the dorsal buccal mucosa on the left lateral side. On the right side of the dental pad there was a 10 cm long, approximately 2 cm deep cavitation present. The overlying buccal mucosa was intact. The cavitation was surrounded by a dark yellow-brown, friable malodorus tissue. The lesion of the right side extended into the right nares. The rostral half of the hard palate lacked a mucosal lining (ulcerated). The rostral one-half of the tongue was ulcerated with a sharp line of demarcation between the ulcerated and normal epithelial tissue lining the tongue. When sectioned, a 2.5 x 1 cm yellow, friable focus was present in muscle of the tongue which extended from the tip caudally.

Histopathological examination revealed that a large portion of the skeletal muscle of the tongue had undergone coagulative necrosis with calcification. The skeletal muscle closest to the dorsal surface of the tongue was viable but had an infiltrate of degenerate and viable neutrophils with edema present in the interstitial tissue. Several large arteries had occluding fibrin thrombi present. The small arterioles appeared hypertrophic, containing 6-8 cell layers of smooth muscle.

This animal was seropositive for BVD at 1:20, and BVD virus was isolated from the blood. Serology and virus isolation attempts for hemorrhagic disease viruses were negative.

The lesions present in the oral cavity are similar to lesions produced in bluetongue and EHD. The gross similarities include ulceration and erosion of the dental pad and glossitis. The histopathological similarities include endothelial hyperplasia in the small vessels underlying lesions present in the oral cavity and also thrombosed vessels in necrotic foci. There was also ballooning degeneration of the epithelium of the tongue with infiltration of neutrophils.

On December 15, 1982, a few days before the previous case, another deer was submitted for necropsy. This was a 5 1/2 year old male that was seen limping badly prior to darting. The deer died as a result of the darting and when examined, was found to be sloughing the left rear hoof. In addition, there were multiple erosive, ulcerative and hemorrhagic lesions on the dental pad and palatine ridge.

Upon necropsy, the foot lesion was determined to most likely be due to trauma or foreign body. The oral lesions could have been related to BVD virus infection but virus isolation for BVD was not attempted. This deer was serologically negative for BVD virus as well as hemorrhagic disease viruses.

Implications

Although BVD virus is capable of infecting white-tailed deer, and there is evidence that such infection can cause clinical disease, neither infection nor disease appears to be widespread in the Cove. This disease does not represent a major threat to the deer herd.

Although BVD can be an important disease in cattle, deer do not represent a major reservoir for the virus. The avoidance of cattle by deer would reduce the possibility of deer to cattle transmission even further. Consequently, the risk to the cattle herd from deer is inconsequential. Cattle are much more likely to become infected from herd mates.

This virus does not represent a risk to other endemic wildlife in the Cove. It is not infective for humans.

INFECTIOUS BOVINE RHINOTRACHEITIS

Infectious bovine rhinotracheitis (IBR) is a highly contagious viral infection of cattle causing tracheitis, rhinitis, fever and occasionally abortion. Little is known about IBR infection in white-tailed deer except that antibodies were found in 4 of 89 white-tailed deer surveyed in New York (Friend and Halterman 1967). Naturally, clinical IBR has not been reported in deer nor was it observed during this study.

Antibody was found in 18 of 50 mule deer (Odocoileus hemionus) in a captive herd in Colorado. Experimental infection of seronegative mule deer in this herd resulted in mild clinical disease, seroconversion and protective titers when challenged 5 weeks after initial infection (Chow and Davis 1964). Experimental infection of two white-tailed deer resulted in low antibody titers (1:4) and no observable clinical disease or gross lesions at necropsy (Karstad 1970).

Methods and Results

Serum samples from the 518 deer captured from 1980 thru 1984 were tested for IBR antibody using the indirect fluorescent antibody test. This technique, as used in this study, is described by Potgeiter and Aldridge (1977).

Twenty of the 518 deer sampled (3.9%) were positive for IBR antibody at 1:5 or greater. The magnitude of antibody titer in these deer is illustrated in Table 34. The location of all seropositive deer is displayed in Figure 24. No specific pattern was noticeable.

Seven of the 20 deer seropositive for IBR (1:5 or greater) were recaptured at some point in the study. Three deer were seronegative for IBR when first captured but seropositive at 1:5 to 1:20 when recaptured. Two deer were seropositive for IBR when first captured but seronegative when recaptured. No distinct pattern regarding the persistence of IBR antibody titer was discernable. Because of the low level of titer, these deer cannot be assumed to have been infected. One deer was positive at 1:20 on November 30, 1982

Table 34. Magnitude of infectious bovine rhinotracheitis virus titer in white-tailed deer, Cades Cove, GSMNP, 1980-1985.

	Dilution					
	1:5	1:10	1:20	1:40	1:80	1:160
Number positive	2	10	5	2	0	1

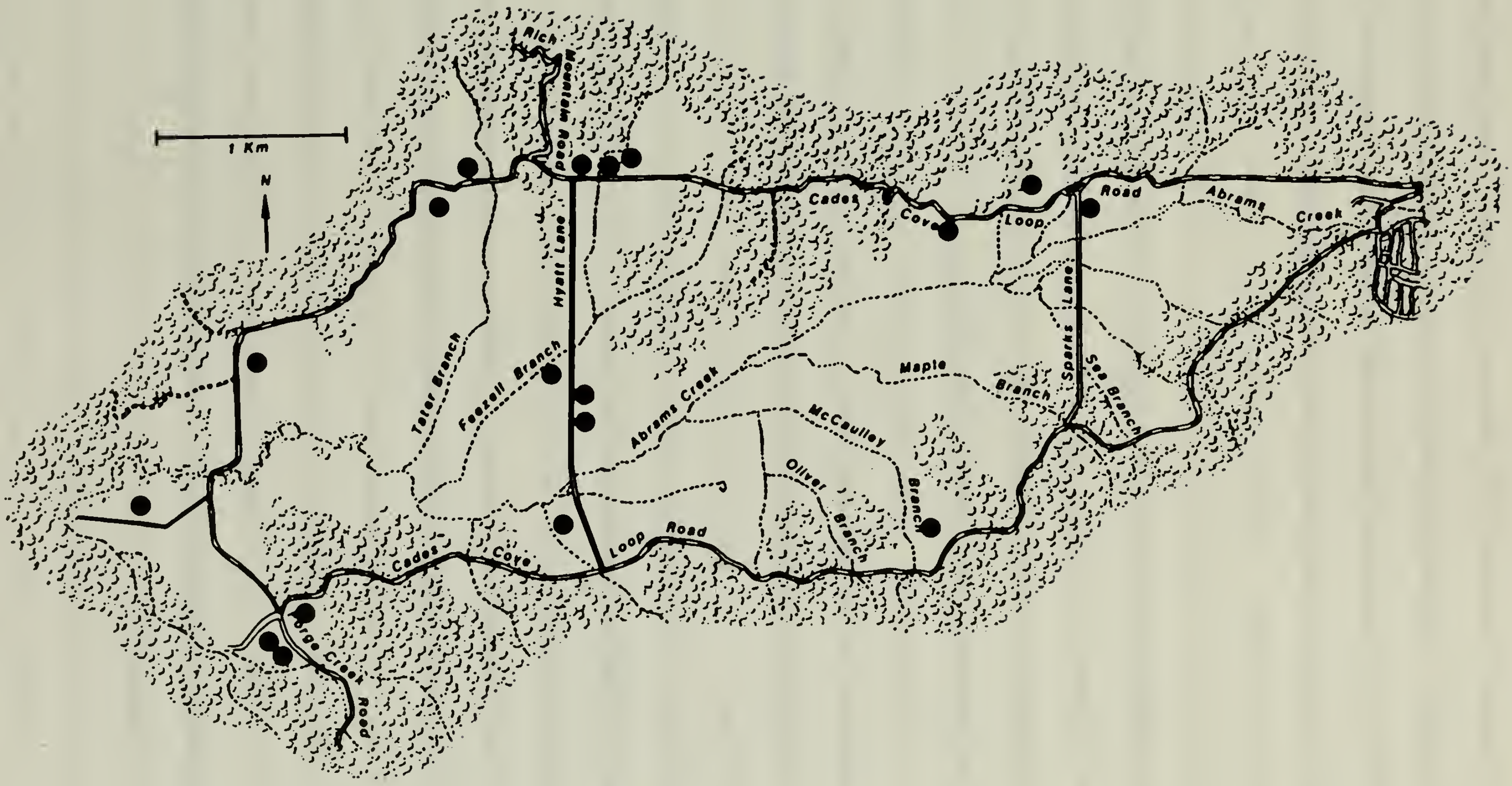

Figure 24. Darting locations of white-tailed deer seropositive for infectious bovine rhinotracheitis virus, Cades Cove, GSMNP, 1980-1984.

and on June 15, 1984, a span of 1 year, 7 1/2 months (562 days). It is unlikely that infection would result in a consistent titer level for this long a period. Consequently, two other explanations are possible. This deer may have been infected at least twice, once prior to each darting or, a titer of 1:20 represents the minimum level of discrimination of the test.

The authors will assume the latter is the case and consider only titers of 1:40 or greater as indication of infection. Under this criteria, there were three deer that were possibly infected.

Of these three infected deer, two (both with titers of 1:40) died in conjunction with the darting. Neither exhibited any clinical sign of illness prior to darting. Field necropsies did not reveal any gross lesions and both appeared to be in good condition. Both were pregnant females (one with twins) with grossly normal fetuses.

The titer of 1:160 was from a serum sample collected on May 1, 1984. When this same deer was recaptured on December 6, 1984, it was seronegative for IBR. This is a span of 219 days. Consequently, the disappearance of titer to natural IBR infection may be less than this span of time.

Blood samples were collected from 56 of the cattle pastured in the Cove. Six (10.7%) were positive for IBR at a level of 1:10 or greater. Two of these animals had titers of 1:20 and one had a titer of 1:80.

This last cow was examined on January 13, 1984, at the request of the owner. She was clinically ill with severe dypsnea, extended neck, mucopurulent nasal discharge and upon auscultation, moist rales and probable areas of atalectasis in the ventral portions of the lung lobes. It is the author's opinion (New) that this cow had pneumonia initiated or complicated by IBR infection. High levels of antibiotics and fluids were administered intravenously but the animal died soon after the examination. The carcass was disposed of by the owner without a necropsy.

The use of vaccination of any kind in the herd was sporadic because of the remote location and difficulty of handling the animals. There was no history of IBR vaccine being used for at least 18 months prior to the clinical case observed in January, 1984.

Partly as a result of this study, IBR and BVD vaccines were administered to some of the animals in this herd by a private veterinary practitioner beginning in January 1984.

Discussion

The presence of IBR virus in the cattle herd is most likely the source of the infection for deer. However, the presence of this virus in the Cove no doubt represents a greater threat to the cattle than the deer.

When infected, there is no evidence that IBR virus is a serious threat to white-tailed deer. There was no evidence at the time of capture that seropositive deer were or had been clinically ill.

Experimental studies of IBR in white-tailed and mule deer have shown that the virus is not shed for more than 5 days after intratracheal innoculation. Furthermore, all experimentally infected deer recovered (Richards 1981).

Implications

The risk of IBR infection to the Cove deer herd is minimal. If transmission were to occur from cattle to deer, the prognosis for the individual deer would be good and the impact on the herd would be insignificant. It is unlikely that the deer represent a reservoir of this virus that could readily spread to cattle. This virus is not transmissible to humans.

ANAPLASMOSIS

Anaplasmosis is a rickettsial disease caused by Anaplasma marginale. The agent is known to occur naturally in white-tailed deer as well as a wide variety of domestic and wild ruminants of North America (Boynton and Woods 1933, Christensen et al. 1960, Howarth et al. 1969, Howe and Hepworth 1965, Howe et al. 1964, Osebold et al. 1959). Although anaplasmosis can be an important and serious disease of cattle, the agent usually produces only a mild anemia in white-tailed deer followed by spontaneous recovery with a persistent, inapparent parasitemia (Kuttler 1981).

The potential role deer may play as reservoir hosts of the agent is an important consideration. As a reservoir host, deer could serve as a source of infection for domestic cattle where the disease is more serious.

Anaplasmosis has been studied in three deer species in the U.S., white-tailed deer, mule deer (O. hemionus) and black-tailed deer (O. hemionus columbianus). Studies of California black-tailed deer have shown extensive serologic evidence of infection. The agent seems to be readily transferred from deer to deer, deer to cattle, and cattle to deer (Boynton and Woods 1933, Christensen et al. 1960, Christensen et al. 1958, Howarth et al. 1969).

Mule deer may also serve as reservoirs of bovine anaplasmosis but are not as important in the epizootiology of the disease as black-tailed deer (Howe et al. 1964, Renshaw et al. 1977, Peterson et al. 1973).

White-tailed deer are the least likely deer species to serve as a reservoir of the disease in cattle. Serologic evidence of infection in white-tailed deer has been documented in several states (Bedell and Miller 1966, Robinson et al. 1968, Smith et al. 1982) but the percent positive was very low.

Serologic evidence of anaplasmosis should usually be considered preliminary evidence. Innoculation of calves with samples from deer suspected to be infected is the best method of confirmation. Blood from experimentally infected deer and cattle will readily transmit the agent when innoculated into susceptible deer (Christensen et al. 1958). Transmission from infected white-tailed deer to susceptible deer or cattle has not been confirmed under field conditions.

Methods and Results

Serum samples from 518 deer were tested for the presence of anaplasmosis antibody using a rapid card agglutination test (Amerault and Roby 1968, Amerault et al. 1972). This test was developed for use in cattle, and has not been used extensively to test white-tailed deer. It has, however been used to test known infected and uninfected black-tailed deer. It proved to have a high degree of correlation with subinoculation data, and when properly conducted, is rapid and accurate (Howarth et al. 1976).

Four Cove deer sera were positive on the anaplasmosis card test. Positive titers were not quantified. Figure 25 illustrates the darting locations of these four deer. There was no spatial pattern noted for anaplasmosis positive deer. Three of these four deer were adult females. The fourth deer was a subadult male. One deer each was captured in 1980, 1981, 1982 and 1984. There was no indication of clinical illness in the three females prior to the darting, nor when examined after immobilization. The subadult male was seen to be limping prior to darting, and died after darting. A field necropsy was performed but no evidence of illness was documented except for a "badly infected and clouded" left eye. It was the opinion of the darter that the deer was blind in this eye. This deer was also seropositive for leptospirosis serovar hardjo (1:250). This darting occurred in December of 1980 and body fat was fair. Cause of death was not determined, but may have been related to the immobilization drug.

Discussion

The serologic results suggest the presence of anaplasmosis in the Cove. Because anaplasmosis was not the main focus of this study, calf innoculation or other tests which would document the presence of the agent were not done.

If anaplasmosis is present in the Cove, it does not seem to be widespread in the deer herd. The cattle sampled were not tested for anaplasmosis so the status of the cattle herd is unknown.

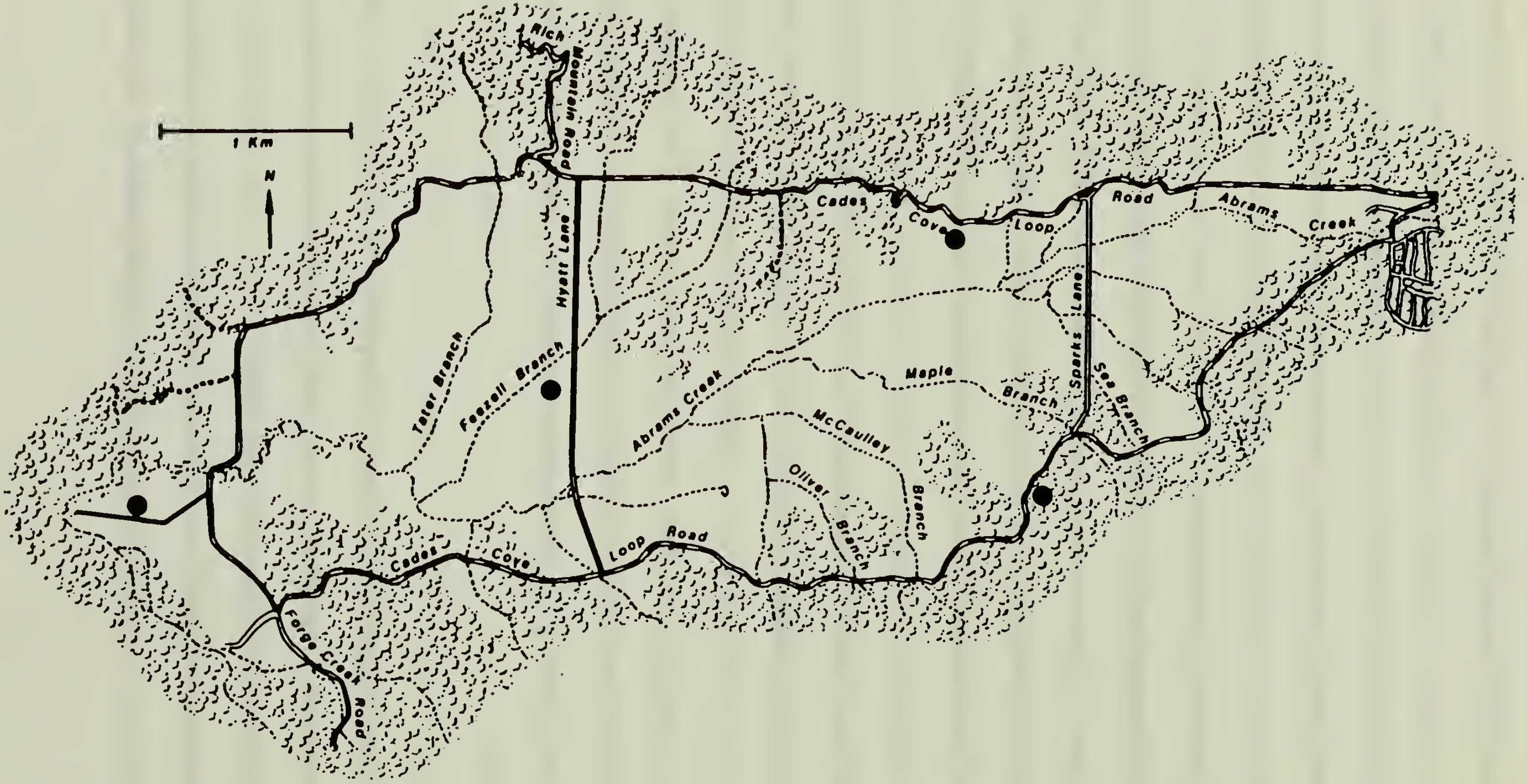

Figure 25. Darting locations of white-tailed deer seropositive for anaplasmosis, Cades Cove, GSMNP, 1980-1984.

Implications

White-tailed deer are not seriously affected by anaplasmosis nor are they a likely source of infection for cattle. There currently appears to be no significant threat to the deer or cattle herds of the Cove, due to anaplasmosis. This agent is not transmissible to humans.

BRUCELLOSIS

Brucellosis is an infectious bacterial disease of several warm blooded animals including man. It is a serious disease of cattle which causes abortion and related reproductive problems.

What little is known about brucellosis in white-tailed deer is based primarily on experimental infections. Brucellosis may cause some of the same reproductive problems in deer as seen in cattle (Youatt and Fay 1959, Baker et al. 1962).

Serologic surveys have not indicated widespread infection in deer. Rinehart and Fay (1981) reviewed all surveys published in the U.S. since 1961 and found a positive antibody titer prevalence of only 0.16% out of 12,706 deer from 24 states.

Five hundred and ninety serum samples from deer were tested for brucellosis using a buffered plate antigen test (Angus and Barton 1983). All deer samples were negative for brucellosis. The cattle herd was not tested for brucellosis as part of this study, but was considered brucellosis free by the USDA nine years ago.

Consequently, brucellosis does not currently represent a risk to the deer or cattle herd. It is unlikely that this agent will be introduced as long as the cattle herd remains closed.

MANAGEMENT IMPLICATIONS

Management of cattle

One management alternative currently under consideration for Cades Cove is the reduction or total removal of cattle from the Cove. This study as well as previous studies in Cades Cove have shown that the deer population utilizes cattle pastures less than other habitats. Telemetry data obtained in this study indicated that cattle impacted movements of deer. Deer with home ranges in cattle pastures had larger home ranges and moved at greater rates than other deer. Since the cattle pastures in the Cove comprise about 1/3 of the available open field area, the removal of cattle would make available a considerable amount of field area that deer do not currently utilize to a great extent. The increased available habitat would likely result in a substantial increase in the size of this deer herd.

Cattle are the most probable source of the leptospirosis serovar hardjo found in the deer. In addition, cattle are the most likely reservoir of hemorrhagic disease viruses and bovine virus diarrhea virus. Although hemorrhagic disease may have devastated the Cove deer herd in the past, the reduction of optimum vector habitat has greatly reduced this threat. Continued exclusion of cattle from areas of standing water would help prevent the establishment of optimum vector habitat.

The impact of leptospirosis and BVD on deer is harder to quantify. BVD probably causes some disease and death in deer but not to an extent to significantly affect the herd. Leptospirosis can cause death and illness but is most likely to cause reproductive problems because of the prevalence of serovar hardjo.

The total removal of cattle would eliminate the primary source of leptospirosis serovar hardjo, hemorrhagic disease viruses, and BVD virus. However, this is probably more extreme than necessary. Specific monitoring of the cattle herd would be more appropriate.

Translocations

Translocations of deer conducted by the Park staff have aided the Tennessee Wildlife Resources Agency in their deer restoration efforts in East Tennessee. Also, such activities provide good public relations for the Park. Spotlight counts conducted during 1978-79 (Kiningham 1980) and 1983-84 (this study) indicate that the population has stabilized at a relatively high density. Whether stabilization was due to the translocation efforts or to other intrinsic factors is unknown at this time. At any rate, the deer herd of Cades Cove also represents a unique opportunity to observe and monitor an unhunted population in a relatively natural environment. It would be of extreme interest to wildlife biologists to have an opportunity to monitor this deer herd on a long term basis without population disturbances such as deer removals or hunting. Long term studies of the Cades Cove deer herd would be very valuable in terms of understanding more about how Southern Appalachian deer populations fluctuate under natural conditions. It would also be of value to the Park to learn if the Cades Cove deer population would eventually stabilize on its own so that deer removals would be unnecessary to ensure the health of the herd. The information gained from high quality, long term studies would be useful to biologists of other agencies charged with managing deer populations where hunting is not conducted, or is undesirable.

Habitat Management

Changes in habitat can significantly impact the manifestation of infectious diseases in the deer herd. Changes that would improve the breeding habitat for Culicoides variipennis could allow an epizootic of hemorrhagic disease similar to the one experienced in 1971. Habitat changes that would increase the deer population would directly increase the risk of an epizootic. Changes that would encourage small mammal populations could also increase the risk of leptospirosis serovars other than hardjo.

RECOMMENDATIONS

I. Continue to monitor the deer herd.

The Cades Cove herd represents a unique opportunity to study a deer population in a natural system, changes in its population dynamics and changes in the levels of infectious diseases. Therefore, we recommend that monitoring of the conditional status of the deer herd be continued by the Park.

1. Blood should be collected to continue monitoring of conditional status and the presence of infectious diseases. This could be accomplished annually with an intense collection period of 1 to 2 weeks. Multiple darting teams could be used with the secondary objective of demonstrating and training in the darting technique. Late July through mid-August would be a preferred time.
2. Productivity rates should be assessed annually by determining if females are pregnant or lactating. This information could be obtained in conjunction with serum collections in July and August. Fawn-at-heel counts are probably not reliable indicators of reproductive rates.
3. Measurements such as age, body weight, antler development and beam diameter should be routinely measured on all darted deer.
4. If time and manpower are available, mark/recapture population estimates of the deer herd should be obtained. During darting exercises, captured deer should be marked with a highly visible ear tag or a collar so that they may be easily identified in the field. Multiple "recapture" counts should be conducted to improve the accuracy of the estimate. Spotlight counts may also be used to census the population. However, these counts should be conducted mostly during late winter and early spring when utilization of the fields by deer is the highest, and a higher proportion of the deer herd is likely

to be observed. Data should be stratified by habitat type to provide more realistic population estimates.

5. Roadkilled deer and other recent kills present excellent opportunities to collect biological samples to enhance the Park's understanding of the Cades Cove deer herd. When opportunities arise, the following samples should be collected:

   1) Serum
   2) Liver, fat and kidney
   3) Reproductive tract.

II. Monitor the cattle herd

This is a closed herd and should remain so. No cattle should be brought into the Cove and the population maintained only by intraherd natality.

Illness and deaths in the herd should be reported and carcasses necropsied if an apparent cause of death is not obvious (e.g. trauma). A blood sample should be collected from animals leaving the Cove for market. This would allow the monitoring of known diseases and help document the emergence of new diseases and conditions.

More specific population monitoring should be implemented. A semi-annual census of the herd by age class (calves to weaning versus adults) would be a minimum level of monitoring. Some method of monitoring the annual calf crop would be one way to evaluate the impact of diseases such as leptospirosis especially serovar hardjo.

Cattle pastures should not be extended beyond those currently being used. An evaluation should be done to determine the feasibility of reducing the pastures currently used by cattle. If some cattle are removed from the Cove or pastures reduced, the deer herd should be monitored closely to determine its response to the change.

III. Expand Intrepretive Information

The aspect of infectious diseases and the role they play in population dynamics should be included in interpretive displays, publications and presentations. The threat of infectious diseases to the deer population, other endemic species, domestic livestock and visitors could be included. Visitors may be interested in infectious diseases as another facet of the ecosystem.

During our study, several fawn mortalities were attributed to visitors that picked up fawns they believed to be abandoned. These fawns were usually taken to the Cades Cove ranger office. A ranger would return the fawns to the area where they were found, but they often died later. Visitors should be instructed in interpretive material not to handle abandoned fawns or sick animals, but to instead report their observations to a Park Ranger.

IV. Evaluate Habitat Changes

Any plans that would result in habitat changes should be reviewed with reference to the potential impact such changes would have on infectious diseases. Habitat changes may discourage or encourage the maintenance of infectious diseases. In addition, the introduction, intentional or unintentional, of new species of animals should be evaluated regarding its impact on the epizootiology of infectious diseases.

RESEARCH NEEDS

During the current study, several areas of research were identified as potential future investigations to expand the Park's knowledge and understanding of the Cades Cove deer population:

1. Vegetation impacts. As a follow up to the study conducted by Bratton (1979a), vegetation plots in Cades Cove should be resampled to document if further damage and changes to plant communities have resulted from the dense deer herd.
2. Cattle - deer interactions. Further investigations should be initiated into the relationship between cattle and deer populations. One such study should concentrate on deer population responses to changes in the size of the cattle herd (in the event of cattle reductions).
3. Impacts of coyotes. An investigation should be initiated to determine the impacts of coyotes and other predators on the deer herd.
4. Population dynamics. Studies on population dynamics (population size, mortality, and productivity) should be continued on a long term basis and be related to observed changes in conditional status such as blood chemistry values, presence of infectious diseases, or other parameters. Studies should be designed to identify factors that limit the deer herd.
5. Infectious disease surveillance. Samples such as blood, tissue and ectoparasites should be collected whenever possible. Intense sampling during a certain time each year would be the most efficient way to continue to monitor the herd's health.
6. Wildlife serum bank. Stored sera should be used to assess the presence or emergence of additional infectious diseases. This bank is currently being used to evaluate the risk of toxoplasmosis and Lyme Disease in the deer herd.
7. Comparison and integration of related studies. Comparison of this study with other studies conducted in the Cove (e.g. Dlutkowski 1985) would help define the impact

of certain infectious diseases. Attempts should be made to integrate research objectives to maximize information gained from wildlife studies. A project that would result in immobilized wildlife could incorporate sample collection to determine the presence of infectious diseases in species other than deer.

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